MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

ABSTRACT OF THE

Proceedings of the Society of Arts,

WITH LIST OF OFFICERS AND MEMBERS,

FOR THE TWENTY-FOURTH YEAR.

1885–1886.

MEETINGS 336 TO 349 INCLUSIVE.

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1885–86 AND 1886–87.

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CONTENTS.

NOTICE.

The SOCIETY OF ARTS, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce. Regular meetings are held semi-monthly from October to May, inclusive, in the Institute building; and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending Oct. 1, 1886, most of the business portions of the records being omitted.

The thanks of the Society are due to the publisher of the *Army and Navy Journal* for the loan of the electrotypes used in illustrating Lieut. Zalinski's paper on "The Pneumatic Dynamite Gun," and to the Creque Manufacturing Company for those illustrating Mr. Creque's paper.

The Proceedings of the six preceding years have been published in the same form as this volume, and the Proceedings of the first seventeen years of the Society are now in active preparation for the press. Copies of the publication may be obtained of the Secretary.

For the opinions advanced by any of the speakers, the Society assumes no responsibility.

LINUS FAUNCE,
SECRETARY.

BOSTON, June, 1886.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-FOURTH YEAR.

MEETING 336.

Relative Poisonous Properties of (Illuminating) Coal and Water Gas.

BY PROF. W. T. SEDGWICK.

The 336th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Oct. 8, 1885, President Walker in the chair.

The minutes of the last meeting were read and approved, several new members were elected, and some matters of business were transacted, after which the president introduced Prof. W. T. Sedgwick of the Institute, who read a paper on "Relative Poisonous Properties of (Illuminating) Coal and Water Gas."

Prof. SEDGWICK said: The recent extensive employment for illuminating purposes of the so-called "water" gas, derived from the decomposition of steam by the action of incandescent coal, and enriched with the vapor of naphtha, has excited a vigorous discussion of the question whether this gas is or is not more dangerous to the public health, when distributed for the purposes of illumination, than the ordinary "coal" gas derived from the destructive distillation of bituminous coal. Up to the present time, although opinions, chiefly *a priori*, have been freely expressed in the affirmative, and especially in the negative, in answer to the question, very little experimental evidence has been available.

In view of the possibility of the general substitution of water gas for the coal gas now in common use in Massachusetts, the question has assumed a large public importance, and, accordingly, under the instruction and direction of the State Board of Health, Lunacy, and

Charity (Sixth Annual Report, 1884, Supplement), an investigation was undertaken by Prof. W. R. Nichols and myself, in the hope of obtaining facts which might serve to answer the question.

Illuminating gas, as ordinarily supplied to consumers, is a poisonous gas, whether it be made from coal, wood, or other organic substances (coal gas, wood gas, etc.), or derived from coal and water by their action upon each other at high temperatures (water gas); but it is never a single gas of uniform composition. It is always a mixture of several gases, and it is the mixture known as coal gas which must be compared with the mixture known as water gas. The composition of these mixtures, as might be supposed, is not always exactly the same, but varies somewhat from day to day in the case of the same kind of gas; and very considerably in the case of the same kind of gas made in different places by different methods. These variations of composition must not be lost sight of, but they are generally within narrow limits, so that the expression "coal gas" or "water gas" stands for a tolerably definite substance or mixture.

It is freely admitted that both gases are poisonous; but there has been hitherto no general agreement as to their relative poisonous properties. This is the more remarkable because the principal poisonous constituent is unusually well known, and its properties have long been recognized. For, whatever importance be attached to the physiological actions of the other constituents of coal and water gas, it still remains true that the only really poisonous substance which is present in any considerable proportion, in either gas, is carbonic oxide.

All the gases in these mixtures (excepting oxygen, which is occasionally present in very small proportion) are irrespirable, *i. e.*, they cannot supply the place of oxygen for breathing purposes, and, if breathed undiluted, will produce speedy death from suffocation.

But besides this negative power, which it shares with the other constituents of illuminating gas, carbonic oxide is conspicuous for poisonous properties which are peculiarly its own. It exerts, for example, a special direct action upon the living blood-cells of the animal body, depriving them of the power of performing their normal functions, and, if present in sufficient quantity, speedily undermines the functions of the whole body.

On the assumption that carbonic oxide is the only essentially poisonous substance in both coal gas and water gas, it might seem

that the question which we were endeavoring to answer could have been settled by experiments upon carbonic oxide itself. Investigations of this sort have, indeed, been made by a number of experimenters, and the only point of disagreement between them is as to the effects of very small amounts of carbonic oxide. It is agreed that carbonic oxide is a powerful poison, but it is still a question whether or not the smallest quantities are wholly ineffective.

For our purposes, however, there could be no doubt as to the desirability of experimenting with the two gases as they actually flow from the pipes of the companies which manufacture and distribute them. This was the more necessary because it has been suggested that other gases beside carbonic oxide, occurring in illuminating gas, may be operative in making up its total poisonous quality. We have given the suggestion its full value, and have arranged our experiments accordingly. At the same time, the close resemblance of the symptoms observed in poisoning by illuminating gas to those produced by carbonic-oxide poisoning should have due weight, as should especially the results of Gruber,* who removed the carbonic oxide from illuminating gas, and then mixed the purified gas so obtained with air in various proportions. In atmospheres of this kind, containing sometimes as much as eleven per cent of the gas freed from carbonic oxide, animals (mice) remained for hours, exhibiting merely some stupefaction, and quickly recovered when taken out.

Without denying, therefore, to the other constituents their proper physiological effects when breathed with air, in a mixture of which they form a large proportion, it is probably true that carbonic oxide is the only component of illuminating gas whose poisonous qualities are at present of practical importance to the public health.

According to the report of the State Inspector of Gas and Gas Meters for Massachusetts for 1884, the average amount of carbonic oxide in a number of specimens of coal gas was 5.53 per cent. The amount of carbonic oxide in the water gas at Middletown, Conn., at the time of the experiment, was 30.5 per cent, and at Athol, Mass., 29.2 per cent.

In the selection of rooms in which to perform the experiment, it was our endeavor to imitate, in a general way, sleeping-rooms of medium size as they actually exist. In no case were windows made

* Archiv für Hygiene, I (1883), 168.

to fit more tightly than usual; the "crack" above the threshold was always left open; while, on the other hand, no unusual holes or other escapes were allowed to remain; so that, in this respect also, we reproduced, as far as possible, the conditions of an ordinary sleeping-room, whose doors and windows are left closed. The rooms, in fact, gave the impression of "close," but not unusually tight, apartments.

All the work upon coal gas was done in a room in Newton Centre, while the work upon water gas was done in other rooms,—some of it in Middletown, Conn., and some in Athol, Mass. But in all cases, whether of coal or water gas, the supply for the experiments was taken from pipes of the local company, and allowed to escape into the apartments through ordinary burners supplied by the local gas-fitters, and connected with meters for the registration of the inflow.

The room in Newton Centre was built in a barn, and made tight by partitions of matched boards. The ceiling was matched and double, with an intervening air-space. The walls were single on two sides, and double on two, and of three-fourths inch boards, matched. The floor was double, and tight. Overhead was an empty loft; underneath was a cemented cellar; and the room, being partitioned off in a corner of the barn, was separated from the barn proper by the single partitions,—from the outside by the single partition, the air-space, and the ordinary wall of the barn. There was one window (about five feet by three) admitting light from without, and two long but narrow windows were built into the partitions for convenience of observation. They fitted into casings in the usual way. One door, of the ordinary size, served for entrance, and, when closed, fitted somewhat loosely, leaving a narrow crack beneath. The dimensions of the room were as follows:—

Length, ...	13 feet 4 inches,	Capacity, 1140 feet.
Hight, ...	9 feet,	
Breadth, ...	9 feet 6 inches,	

It contained two shelves and one two-story pine table. The gas-fixture was a cheap, plain, four-arm chandelier hanging from the middle of the ceiling. A meter was connected, and located for convenience in the barn, where the observer could easily read it at any time.

One of the rooms in Middletown, Conn., contained a little less than 2000 feet, free space, and was furnished with one very large

window, and two doors. It was plastered, but not free from cracks. Dimensions, 11 × 12⅛ × 15.

The dimensions of the other room at Middletown, Conn., were as follows: —

Hight, ...	7 feet 8 inches,	Capacity, 1336 feet when empty.
Length, ...	14 feet 4 inches,	
Width, ...	12 feet 2 inches,	

From this, however, must be deducted several heavy pieces of shelving, cases, etc., estimated roughly at 150–200 feet. It will be seen that the room, therefore, compares very well as to shape and contents with the room at Newton. But it had plastered walls, two doors, and two windows, and not in the best repair, and stood upon an exposed corner. On the whole, however, it was a tolerably close but not a tight room; less tight, if anything, than the room at Newton.

The dimensions of the room at Athol, Mass., were as follows: —

Hight, ...	8 feet 2 inches,	Clear capacity, 816 cubic feet.
Breadth, ...	10 feet 2 inches,	
Length, ...	9 feet 10 inches,	

From this, however, must be deducted about 100 feet occupied by a chimney, a bench, a large case, etc.

Different animals, usually of several species, were placed in different parts of the room — on the floor, on the table, on the shelves, etc. — before the experiment began, and their symptoms carefully noted as the experiment went on. Samples of the atmosphere which they breathed were taken from time to time by entering the room and emptying into a vessel demijohns (generally holding one gallon) previously filled with water. These were carefully stopped with solid corks, then taken from the room and immediately sealed with melted paraffine. The time the samples were taken was carefully noted, and they were afterwards analyzed.

The following is a condensed table showing approximately the results of the experiments upon animals: —

Number of the Experiment.	Kind of Gas Used.	Greatest Inflow per Hour in Cubic Feet of Gas.	Estimated Capacity of the Room in Cubic Feet of Air.	Highest Percentage of Gas observed during the Experiment.	Number of Animals Exposed in the Experiment.	Effects noted from exposure of the animals to the mixed gas and air after— 1 Hour.	2 Hours.	3 Hours.	4 Hours.	5 Hours.	6 Hours.	7 Hours.	8 Hours.	9 Hours.	24 Hours.
I.,	Coal,	38	1,140	-	8	None.	Drowsiness.	Discomfort.	Slight effects.	-	-	-	-	-	-
II.,	Coal,	36	1,140	-	8	None.	None.	-	-	-	-	-	-	-	-
III.,	Coal,	50	1,140	3.0	6	None.	Drowsiness.	No further change.	No further change.	No further change.	-	-	-	-	Slight effects.
IV.,	Water,	52	1,900	3.3	5	General insensibility.	Two dead.	Three now dead.	-	-	-	-	-	-	-
V.,	Water,	37	1,150	1.1	4	Severest symptoms. One dead.	- -	-	-	-	-	-	-	-	-
VI.,	Water,	8	1,150	0.7	5	Slight effects.	More marked.	Still more marked.	Vomiting. Convulsions. Insensibility.	-	-	-	-	-	-
VII.,	Water,	15	1,150	0.9	8	Slight effects.	Muscular relaxation. Insensibility.	Insensibility. Convulsions.	Gradual increase in severity.	One dead. All badly off.	Three now dead.	Increased severity of symptoms.	Four now dead. Experiment closed.	-	-
VIII.,	Water,	6	725	1.0	4	Salivation. Urination.	Vomiting, &c. One dead.	Three now dead.	-	-	-	-	-	-	-
IX.,	Water,	6	725	1.0	7	Marked effects.	Insensibility. Vomiting.	Two dead.	Three dead.	Four dead.	Gradual decline.	Still more marked.	All dead.	-	-
X.,	Coal,	6	725	0.9	8	No change.	No change.	Slight effects.	Salivation, and more marked effects.	No further change.	No further change.	Marked symptoms.	No further change.	Symptoms somewhat more marked.	Two dead. The rest stupefied.

I will now give the results to which our experiments have led us, and also certain practical conclusions which naturally follow: —

I. With ordinary gas-fixtures it is generally difficult to get more than three per cent of illuminating gas into an ordinary room. By using one burner alone, it is difficult to exceed one per cent.

II. With coal gas it is a matter of some difficulty to get into an ordinary apartment, through the ordinary burners, gas enough to produce upon healthy animals distinctly poisonous effects. With water gas, on the contrary, it is comparatively easy to get into an ordinary apartment, through the ordinary burners, gas enough to produce poisonous and even fatal effects.

III. It does not follow that because one illuminating gas contains three, four, or five times as much carbonic oxide as another it is therefore only three, four, or five times as dangerous to life.

IV. Our experiments confirm the work of Gruber and others, who claim that carbonic oxide is not a cumulative poison,— that is, the breathing of a small quantity for a long time is not equivalent to the breathing of a large quantity for a short time. A similar conclusion may be drawn for all the constituents of illuminating gas.

We may now illustrate the foregoing conclusions by examples drawn from our own experiments. And, first, as to the difficulty of charging rooms heavily with illuminating gas. (Expt. III., page 18.)

A room containing 1140 cubic feet of space was supplied with four ordinary burners. Through these there entered the room at a tolerably constant rate during twenty-four hours 1200 feet of coal gas. Yet, at the end of the twenty-four hours, the top of the room just above the burners contained a mixture of gas and air of which the former composed only three per cent, while the lower portions of the room showed less than one per cent. Again (Expt. V.), a room holding about the same amount of air, received fifty-five feet of water gas during one and a half hours. At the end of that time the largest amount discoverable in the room was 1.1 per cent of gas in the whole mixture of gas and air.

To illustrate the second conclusion, viz., that it is somewhat difficult to get in enough gas by the ordinary fixtures to kill, if the gas be coal gas, but relatively easy if it be water gas, it is only necessary to note the effects of the two experiments just quoted. In the former (coal gas), after twenty-four hours, the animals, though somewhat

drowsy and stupefied, were not seriously affected, while in the latter, after one and a half hours only, similar animals showed most alarming symptoms, and one was dead from the effects of the gas. From other experiments it is certain that, had this experiment been long continued, others, and probably all the animals, would soon have perished.

Similar considerations illustrate the third conclusion, for it is impossible to say that in the latter case the animals were only four or five times worse off than in the former. It is plain that, as their lives were in imminent danger, and as they were vomiting and in distress, it is not possible to express their relative danger mathematically. The first experiment just mentioned also indicates that carbonic oxide is not cumulative, for exposure to a small amount for twenty-four hours led to no serious consequences.

As to the time required to produce poisoning: this seems to be merely the time required to attain a poisonous percentage of carbonic oxide; and this clearly depends on the rate of inflow, the size of the room, the leakage, etc.

In view of the foregoing conclusions, based upon experimental evidence, it seems to us that it must be admitted by all that water gas, with its thirty per cent, more or less, of carbonic oxide, is a more dangerous substance than coal gas with its six per cent or seven per cent of carbonic oxide.

MEETING 337.

Recent Progress in Under-Ground Wires.

BY MR. W. W. JACQUES.

The 337th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 22nd, Prof. C. R. Cross in the chair.

After the reading of the minutes of the last meeting, the chairman introduced Mr. W. W. Jacques, who read a paper on "Recent Progress in Under-Ground Wires."

Mr. JACQUES said: Last winter I had the honor of appearing

before this Society, and reading a paper on under-ground telegraphy. That paper was chiefly historical, and described the various attempts that had been made to lay wires under ground in Europe from 1840 down to that time.

This evening I propose to call your attention more especially to the progress that has been made in methods of laying electrical wires under ground during the past few years.

Ten years ago the number of wires in use in our American cities was small compared with those in use today. The telephone — the wires connected with which perhaps outnumber those used for all other purposes in cities — was entirely unknown.

Electric lighting had not come into practical use, and the number of telegraph wires was far less than that in use at the present day.

In our American cities, at that time, none of the wires were placed under ground, as electric cables were used only for the crossing of rivers and streams, and such cables were made almost exclusively of gutta-percha-covered wires, because gutta-percha, when kept continually wet, is an excellent insulator, and very durable.

The introduction of the telephone and the electric light, together with the increase of telegraphic communication, has given rise to a great cobweb of wires, extending over the business portions of most of our large cities. So long as there were comparatively few wires overhead, little objection was made to them ; but the immense increase of the last ten years, together with the probable large increase in the future, makes it desirable, on the part of the companies operating these wires, as well as on the part of the public, to have them gathered together in some systematic way, and, if possible, to place them under ground.

The objections to overhead wires are that, where they are numerous, they are continually coming in contact with each other; or, as it is technically called, "crossing up," and it is well known that, when this takes place, one or both of the wires is rendered entirely useless.

In the case of the telephone wires, a large force of men is continually employed in running over the roofs to detect and remove such crosses, and even then the telephone often fails to work just when it is wanted, simply because the wire is crossed with some other

wire between the subscriber's station and the central office. Another objection to overhead wires is the annoyance to the tenants of buildings caused by the line-men tramping up and down the stairs, and over the roofs, to construct or repair the wires.

If the wires, instead of being carried over house-tops, are carried through the streets on poles, not only are the poles obstructions to travel, but they and the wires strung upon them are exceedingly unsightly, and it has been repeatedly proved that they are great hindrances to the operations of firemen in case a building, in front of which these wires are strung, is on fire.

But perhaps the greatest objection on the part of the parties operating them is the fact that every two or three years there comes a heavy sleet storm, followed by wind, and the wires not only become entangled, but break, and come tumbling down so as entirely to interrupt communication, and to cause enormous expense for reconstruction.

The annual cost of repairs of overhead wires in cities is not less than thirty per cent of the first cost of construction. These various objections to overhead wires have caused the companies to look about to see what could be done in the way of gathering the scattered wires into cables, and, if possible, to lay such cables under ground.

It is for the interest of the companies, quite as much as for the public, to have this problem solved, and the American Bell Telephone Company has spent large sums in an endeavor to find a practical method of placing the wires of an exchange system under ground.

The difficulties met with have been great, and they have not yet been sufficiently conquered for me to say that it is both technically and economically possible to put all of the wires of any exchange system under ground; but the problem has been so far solved that it may be said to be practicable to run from the central office under ground to a considerable number of points, so located that one or another of them may be reached by a short overhead wire from any subscriber's station.

With regard to the burial of telegraph wires: this has been done for years in all the European cities, and can, of course, be done in the same way here.

There is a great difference, technically, between the operation of telegraph and telephone wires. If two or more telegraph wires are

bunched together into a cable of such length as would be used in our largest cities, each wire continues to work practically as well as before, and each wire works entirely independently of the neighboring wires in the same cable. This is true even of the old-fashioned cables in use ten years ago.

When, however, it was first attempted to bunch telephone wires into cables, serious technical difficulties were met with. In the first place, it was found that conversation was very much lowered in intensity when, instead of speaking over an overhead wire — say five miles in length — it was attempted to talk over a cable-conductor insulated with gutta-percha of the same length. But, worse than this, it was found that conversation carried on over one wire was heard with equal facility on all of the other wires in the same cable.

This decrease of intensity is due to what is known as retardation, by means of which each signal, instead of being sharp and distinct, is partly kept back, so that it overlaps, and mingles with the next. In the case of a telegraph instrument, the signals do not succeed each other with sufficient rapidity for the retardation to be noticeable on lines of such length as would be used in any of our cities.

In the case of the telephone, the electrical undulations in the wire, by means of which speech is transmitted, necessarily succeed each other some three hundred times per second, and in a gutta-percha cable, five miles in length, a considerable retardation and consequent overlapping of the signals, resulting in a diminution of the intensity of conversation, are felt.

The overhearing, or cross-talk, may be due either to a direct leakage between the conductors, or to what is technically known as induction, by means of which signals sent on one wire cause fac-simile signals in all the other wires, even though there is no direct passage of electricity from one wire to the others. Here, too, in the case of telegraph apparatus, the induction is not sufficient to affect even the most delicate apparatus in use. In the case of the telephone, however, the induction is amply sufficient for overhearing in a gutta-percha cable five miles in length.

The retardation in any cable is directly dependent on the specific inductive capacity of the material used to insulate each wire from its neighbors; and it is evident that a cable which will present the least

retardation is the one whose insulating material has the lowest specific inductive capacity.

The cross-talk — so far as it is due to leakage — is, of course, prevented by using an insulating material of very high insulating power. So far as it is due to induction, we also want to choose an insulating material of low specific inductive capacity, for the cross-talk is directly dependent upon this quality.

The requisites of a cable, then, in order that it may transmit speech without cross-talk, are good conductivity, high insulation, low specific inductive capacity.

Below is a table showing the specific inductive capacity and insulation of various insulators. The measurements were all made on a wire 0.05 of an inch in diameter, coated with insulation to a thickness of 0.10 of an inch: —

CABLE.	MAKER.	Insulation per mile in megohms.	Specific inductive capacity.
Gutta-Percha, .	Siemens Brothers, London, ...	190	4.2
India-Rubber, .	Rattier, Paris, ...	170	3.7
Kerite, ...	A. G. Day & Co., New York, ...	150	4.0
Faraday, . . .	Faraday Cable Works, Cambridge, Mass.,	15,000	1.6
Patterson, . . .	Western Electric Co., Chicago, ...	450	3.1
Brooks, ...	David Brooks, Philadelphia, ...	-	2.8

Let us take a special case, and compare a gutta-percha cable, having a specific inductive capacity of 4.2 with a Faraday cable of 1.6.

The table predicts that we can talk three times as far with the latter as with the former, and experiment proves it. The cross-talk on the gutta-percha cables ought to greatly exceed that on a Faraday cable; and experiment has shown that, while conversation over a two-mile gutta-percha cable was continually disturbed by existing cross-talk, conversation was carried on over a similarly-constructed Faraday cable, five miles in length, without cross-talk being appreciable.

We have seen, from our table, that india-rubber and kerite, both of which are extensively used for telegraph cables, are equally unfit

with gutta-percha for telephonic work, on account of their specific inductive capacity being nearly as high as that of gutta-percha.

There are two other cables mentioned in the table. The Patterson cable, which has a specific inductive capacity of 3.1 against 4.2 for gutta-percha, and the insulation of which, when new, is 450 megohms per mile, against 190 on the part of gutta-percha. The table predicts that a Patterson cable — which consists of cotton-covered wires soaked in paraffine, and drawn into a lead pipe — ought really to be more suitable for telephonic work than is a gutta-percha cable, and experience bears out this prediction.

There is one fatal objection to the Patterson cable, which has been proved by experience with it in France, Germany, and other places: the insulation, although high at first, gradually decreases, and experience has uniformly shown that, after several years of use, this insulation falls so low that cross-talk easily appears, due to direct leakage.

Patterson cables, of course, under different names, were used years ago in France and Germany, and were looked upon with a great deal of favor when first introduced, but the gradual failure of insulation has caused them to be almost entirely abandoned abroad.

Another cable referred to is the Brooks, which consists of copper-covered wires wound with cotton, and drawn into iron pipes, which are then filled with petroleum.

The specific inductive capacity of a Brooks cable is only 2.8 against 4.2 on the part of gutta-percha, and on this account it is suited to telephonic purposes. The Brooks cable, however, like the Patterson, does not retain its insulation, and, indeed, the difficulty of maintaining good insulation in the Brooks cable is far greater than in the Patterson, for it is almost impossible to make the pipes so tight that the petroleum does not leak out, or water leak in.

In the table, I have assigned no value to the insulating power of the Brooks cable, for when the pipes are thoroughly dried, and the cables, after being thoroughly dried, are drawn in, and the pipes are filled with dry oil, the insulation is enormous, and such a cable gives wonderfully good results when used for telephonic purposes, talking excellently well, and being remarkably free from retardation and cross-talk due either to induction or leakage.

The insulation, however, falls continually, and at the end of

three or six months, if it be of any considerable length, will have fallen so low that talking on one conductor can easily be heard on all of the other conductors, because of direct leakage. Because of this difficulty of maintaining insulation, the Brooks cable, after being tried in England, France, Germany, and elsewhere, as well as in the United States, has been generally abandoned.

The makers of the Faraday cable claim that the enormously high insulation, which certainly does exist in it when it is new, can always be maintained, and, of course, there is no reason why its specific inductive capacity, which is the most essential feature, should ever change at all. German counterparts of the Faraday cable have been in use six or seven years, and experience has shown that they have not changed materially in insulating power.

We have seen that, if we were to attempt to construct an underground telephone system, say five miles in length, using gutta-percha-covered wires in cables, we should find difficulty in talking over any one of these conductors, and we should find that conversation on one wire was heard with almost equal facility on the other wires.

If, however, we use, instead of gutta-percha, a Faraday cable, we find in practice that, because of the high insulation and the extremely low specific inductive capacity, we are able to talk over a system of cables five miles in length with perfect facility, and without serious interference from cross-talk between the neighboring wires.

While at Mülheim, in Germany, last summer, I talked over such a system. The makers had constructed a cable five miles in length, and at each end had run the conductors out to a number of stations by means of short overhead wires. The cable was laid back and forth in an open field. Electrically it was exactly the same as if it had been placed under ground. In other words, we had a complete underground telephone exchange-system, with wires running side by side at as great a distance as five miles, and this is as extensive a plant as we shall ever have occasion to use. The statement that the wires in the Paris telephone exchange, which counts over three thousand subscribers, are placed under ground, is true, and it is further true that gutta-percha cables are used. These cables are constructed in a peculiar way. Each circuit, instead of consisting of one wire extending from the central office to the subscriber's station, consists of two insulated wires twisted spirally, the current going over one wire and

returning over the other. Many such pairs of conductors may be bunched together into cables for as great distances as five miles without cross-talk. For in each pair of conductors there are equal and opposite currents which, either by leakage or induction, would tend to produce equal and opposite currents in either branch of any neighboring conductor, or, in other words, no current at all.

This device, therefore, prevents cross-talk, whether due to leakage or induction, and, with cables constructed in this way, the retardation is at a minimum, although experience shows that it is much easier to talk over five miles of single-conductor cable made on the Faraday plan than it is to talk over five miles of metallic gutta-percha cable, such as is used in Paris.

The retardation in Paris is, however, not large enough to be an obstacle for as great distances as it is ever necessary to use within the city. If it were desired to talk through such conductors, and then out across the country to neighboring cities, as we have occasion in America, it is an open question whether the retardation would not become a serious obstacle.

A great objection to the metallic circuit cable is that it requires two wires for each subscriber, which, to say the least, doubles the cost. Moreover, there has never yet been devised any real practicable method of connecting a metallic circuit system with a single circuit system so that conversation could not be carried on between parties in one city and parties in a neighboring city, unless both cities, as well as intervening trunk lines, were constructed with metallic circuits.

Thus far we have merely discussed the electrical difficulties which are met with when we take our wires down from the house-tops and poles, and bunch them into cables, to be laid under ground.

A bird's-eye view of the wires in any of our cities would show that there is an enormous engineering difficulty in the way of placing absolutely every wire under ground. The best solution of this difficulty has been found to be to radiate, by means of cables containing a hundred or several hundred wires, from the central office to a considerable number of points so located about the city that one or another of them could be conveniently reached by a short overhead line from any subscriber's station. This has been done to a considerable extent in many American cities by means of cables carried over-

head. There is no reason other than that of increased cost why these same cables should not be put under ground; in fact, in many cities — in Pittsburg and in Washington, for examples — this has been done.

In this way by far the greater part of the wires may be placed under ground at an expense not greatly in excess of an overhead system. But it is easy to see that, if it were necessary to go a step further and place the overhead lines diverging from the points of radiation to the subscribers, also under ground, there would be an enormous additional expense, for it costs nearly as much to put one wire under ground as fifty, since the expense of excavating, laying the conduit, and refilling would be practically the same.

With regard to the method of laying the cables under ground, this must vary with the conditions present in the different cities.

In Washington, for example, where the streets may not be taken up for other purposes, it has been found sufficient to lay the cables in wooden troughs, filled with asphalt, about two feet below the surface of the street.

In some of the streets of Boston, which are continually being disturbed, it has been found necessary to construct under ground chambers at crossings, connected by means of wrought-iron pipes, through which the cables may be drawn. These, however, are engineering difficulties, and are easily settled for each particular case. While there exists no technical obstacles to the placing of all wires of a telephone exchange under ground, I do not, by any means, consider that it is economically practicable. It is practicable to extend wires from the central office under ground out to a considerable number of points, some one of which shall be easily accessible by a short overhead line from any subscriber's station, and when we consider that such a system is more durable than an overhead system, requiring practically no expenditure for repairs, and being always in good order, it is, in the long run, perhaps more economical to place the wires in this way than entirely overhead.

At the conclusion of Mr. Jacques's paper, Prof. CROSS said, among other things, that he had had occasion recently to compute the size of wire, and the thickness of insulation needed for an Atlantic cable for telephonic purposes, according to the figures given by Mr. Jacques in his paper read before the Society last winter.

The method of computation used was the one which would most naturally suggest itself, there being a variety of methods possible. He found the diameter of the wire itself would have to be three inches, and the diameter of the completed cable thirty-nine inches.

MEETING 338.

Improvements in Steam-Heating.

BY MR. FREDERIC TUDOR.

Application of Solar Heat to the Warming of Buildings.

BY MR. S. H. WOODBRIDGE.

The 338th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Nov. 12th, at 8 P. M., Prof. C. R. Cross in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the chairman introduced Mr. F. Tudor, of Boston, who read a paper on "Improvements in Steam-Heating."

Mr. TUDOR said: The two objections to steam-heating are water-hammering and absence of control of temperature. The first is the result of bad design or workmanship, or of mismanagement of the valves. I shall try to show how both can be obviated. The circulation depends upon gravity, and upon very slight differences of pressure in the several parts of the apparatus, this difference of pressure having no necessary relation to the boiler pressure. Whether the boiler pressure be ten pounds or one hundred pounds, the circulation is not affected, except that difficulties may arise from a difference in the rate of condensation, which is greatly increased by greater pressures, since high-pressure steam has a higher temperature than low-pressure steam. The flow of steam through the great length of pipes, necessary in most cases, is attended by friction and a consequent reduction of pressure at remote points. In a well-proportioned appa-

ratus these reductions of pressure will be very slight, and, when they are sensible, suitable arrangements must be made to overcome their effects. [The speaker then explained some diagrams on the board, bringing out very clearly the points mentioned above.] If the pressure were the same throughout the apparatus the water would be level, but when the circulation is going on, with a diminished pressure in the radiator, it is clear that the level of the water in the return-pipe will rise to a hight above that in the boiler equal to the hight of a water-column which balances the difference of pressure. For example: if the difference of pressure between the boiler and radiator is one pound, the difference of level will be two feet three inches. Where this difference becomes sufficient to sustain a water-column higher than the difference of level between the water-line of the boiler and the lowest part of the radiator, water enters the latter from the return-pipe, and water-hammering begins. In such apparatus this defect can be obviated by limiting the boiler-pressure so as to reduce the difference in pressure on which the hight of the water-column depends. In a well-proportioned apparatus this difference will not exceed one pound, while the difference of level provided is usually four feet.

Up to this point we have only supposed one radiator. Let us consider a number of them, horizontally disposed, with a return-pipe common to all, and for most of its length above the water-line. In such a case there would be no appreciable loss of pressure in the nearest radiator, and the steam, passing down through it, would establish the same pressure on the main return-pipe. At the most distant radiator there would be a lowered pressure, consequently the movement in the return-pipe would be toward it rather than toward the boiler. The result would be that the condensation-water, being transferred to the point of lowest pressure, would accumulate there, obstructing the circulation and causing incessant noise.

If we change this horizontal system into an inclined one, a degree of inclination will be reached where the movement of the water, due to gravity, will have sufficient force to overcome the friction of the steam moving past it in the return-pipe on its way to restore the pressure in the more distant radiators, and the water will then reach the lowest point rather than the point of least pressure. If, now, we continue to increase the inclination of our horizontal sys-

tem until we reach the vertical, we shall have the common type of radiators disposed vertically, with upright rising mains, and the reason circulation is good, notwithstanding a largely reduced pressure is sufficiently clear.

If, in the horizontal system, the main-return is placed below the water-line, the loss of pressure in the radiators will be balanced in the return-pipe by an elevation of the water-columns in the upright branches, and the circulation will be perfect, notwithstanding the differences of pressure.

The details of the apparatus I have described are commonly supposed to be especially suitable to a low pressure,— that is, of two or three pounds per square inch; but, since the circulation does not depend upon pressure, the system is suitable for any pressure. In passing, I will say that a high-pressure apparatus, so called, is one so badly proportioned that there can be no return to the boiler of the water of condensation which accumulates at the remotest point, where there is the greatest loss of pressure, whence it must be removed by special apparatus.

It has appeared that, in an apparatus of good design, slight differences of pressure are unavoidable, but that there must be a limit beyond which they must not go. Suppose, now, we limit the boiler-pressure, so that it shall not exceed that of a water-column whose hight is equal to the difference of level between the water-line of the boiler and the bottom of the radiator. We can then impose an artificial obstruction in the steam-pipe and graduate its flow, even shutting it off altogether, without deranging the circulation in other radiators. This obstruction is the steam-valve, which, under these conditions, we can open more or less, and obtain more or less heat. We cannot usually do this, because the pressure is too high in the case of horizontal systems having the returns sealed by water-columns; and in the vertical systems, the returns not being sealed, there would be a reversed current in the returns if the supply were throttled, steam would flow in from the return-end and the condensation-water would be driven back and retained in the radiator. Consequently, there is no control of the supply of steam and of the heat emitted; the valves must be wide open or tightly closed.

The method of regulating the heat by limiting the pressure, and thus affording a control over the steam-current in horizontal water-

sealed systems, has long been known, and ought to be availed of oftener. I have been able to accomplish the same result in vertical systems in the following way: we have seen that the ordinary vertical system is simply a development of the horizontal system, and that the defects of circulation disappeared in the change of elevation, and also that the horizontal system circulates perfectly by sealing the returns. I have obtained the feature of the sealed returns in the vertical system by carrying them down the hight of one story before connecting them to the main return, and by placing in each a check-valve at the point of connection, which closes automatically against a pressure in the main return. This is the condition when the radiator connected to it has the steam shut off. If the steam-valve should be opened a little, the condensation-water will accumulate above the check-valve until the hight, or head, is sufficient to overcome the pressure in the main-return pipe, when discharge begins, and further accumulation is prevented. The steam-valve may be opened wider, or set at any point, to supply steam to meet the exact demands for it. When it is fully opened, the water in the branch-return all escapes, and is not again checked until the steam supply is diminished.

By means of these appliances the great advantage of controlling the heat, without complicating the management, is secured. In fact, the management is simplified, since there is only one valve to manipulate, and it may be left in any position. With the common two-valve system, if the valves are left in a position different from the necessary one, of both fully open or both tightly closed, the circulation will be obstructed, and water-hammering will ensue. A simpler arrangement depends upon the fact that, with a fixed pressure and given orifice, the rate of discharge is uniform; also, that a given condensing surface exposed to a uniform exterior temperature and interior pressure will condense steam to water at a uniform rate. Given the pressure and the size of the radiator, a valve can be constructed which, when wide open, will discharge the same weight of steam in a given time that the radiator can condense. There is no surplus steam to escape into the return-pipe, and to supply radiators by reversed currents entering through the return-end, consequently no return-valves are necessary; and, since the maximum discharge just fills the radiator, a reduced discharge only partially fills it; heat may be supplied in any quantity desired; hence the "fractional valve."

This valve will be acceptable to all those people who have learned that steam-radiators must be either fully turned on or wholly shut off, and have asked why we cannot turn on steam just as we do gas or water, and graduate the discharge in a similar simple way.

In conclusion, I think I may say that the ground we have gone over brings us to a point whence we can see the two main objections to steam-heating overcome; we can prevent noise in the pipes and graduate the temperature, and, while we have not complicated the construction, we have greatly simplified the management.

In the discussion which followed the paper, in reply to a question as to the relative values of the different methods of heating,—that is, by the old-fashioned fire-place, the furnace, and steam,—Mr. Tudor said that undoubtedly the fire-place was the most cheerful, but, on account of the enormous draft occasioned by large fires, the influx of cold air near the floor caused great variations in temperature at different parts of the room. If this entering air was moderately heated (not too warm as to spoil the draft), this method would perhaps be the best. Heating by a furnace, as compared with steam, is simpler and more manageable, especially in regard to the control of temperature, but it is only suitable to very compact houses, unless several furnaces are employed. Heating by steam gives the very great advantage of transferring the heat to comparatively distant points, and the objection to it is mainly in the lack of control of temperature in the apparatus as generally supplied. The quality of furnace-heating has been much lowered by competition of manufacturers, who now seem to aim to catch purchasers by some taking mechanical detail rather than by general excellence. The most thorough work in furnace-heating is cheaper than the poorest, as well as better, in some cases, than the best work in steam, yet the furnace men have been so occupied by their struggle to sell the cheapest heater in the market that they have lost sight of the fact that they could compete in merits with steam as well as in price.

APPLICATION OF SOLAR HEAT TO THE WARMING OF BUILDINGS.

The chairman then introduced Mr. S. H. Woodbridge, who read a paper on the "Application of Solar Heat to the Warming of Buildings."

Mr. WOODBRIDGE said that the following paper was based on theoretical rather than experimental investigation. His attention was first called to the effect of solar heat in the warming of buildings by the excessive amount of coal burned in heating the new building of the Institute during a winter of exceptional cloudiness and of mean temperature and wind travel. It was found, however, that in many other similarly exposed buildings the amount of coal burned was the same as usual, and that the increased consumption at the Institute was due to local causes in the boiler-room rather than to a cloudy sky.

Solar heat is only available for heating purposes while the sun's rays are unobstructed by clouds. Cloud-charts were, therefore, constructed from the signal-service records of consecutive *day*-observations at four-hour intervals, covering the winter months of several years, and it was found that an average of more than half the day the sky is cloud-covered in ordinary winter weather. The charts made up from the three consecutive *day* records give far more correct information of the amount and time of cloudiness than could be had from the official statement of the service, since it classifies sky-conditions under three heads,— clear, fair and cloudy,— and includes one night-observation at an hour when the sky is more likely to be clear than at the corresponding day-observation. A day is officially clear if the mean of the three observations of cloud-covered sky falls below 0.27, or fair if that mean falls below 0.73, and cloudy only when it is above 0.73. Thus, a day may be officially fair which has been cloudy from morning till night, the clouds clearing away by 11 o'clock P. M. The seven months from October to April of a year, taken at random, gave 0.4 more cloudiness for the season by taking the 11 A. M. rather than the 11 P. M. observation. These preliminary observations were made to demonstrate the uncertain value of weather-reports for the purpose of this study. [The speaker then described the method of constructing the charts, and two, for different years, were exhibited.]

Although the maximum heat yielded by a zenith-sun, in clear air, on a normal surface, at the sea level, is 42.7 thermal units (British), or enough to raise a layer of water one inch deep 1° (F.) per minute, yet only a fraction of that heat is available, because the clouds curtain the sun more than half the time, and its rays can fall normally on a fixed surface for no more than a few minutes daily, and

because of the loss of heat due to the increased depth of atmospheric medium through which the sun's rays pass as its distance from the zenith increases. In considering the solar heat absorbed by a vertical solar wall, Mr. Woodbridge estimated the losses due to all causes as follows: —

By cloudiness, ...	0.55,	remainder,	0.45
" frame obstruction, ...	0.05,	"	0.427
" angle of incidence and atmospheric absorption,	0.40,	"	0.256
" reflection from glass surface, ...	0.10,	"	0.231
" reflection from slate surface, ...	0.05,	"	0.22
" cooling through glass, ...	0.20,	"	0.176

$42.7 \times 0.176 = 7.52$ B. T. U. per square yard per minute would, then, be the mean heat available through the day hours of the winter season. This estimate he considered high rather than low. It makes the thermal value of a square yard of Southern and vertical sun-exposure, for the six winter months, equal to eighty-one pounds of coal, and twenty-five square yards would yield the heat given by a ton of coal. But coal costs less than $5 per ton to large consumers, and if the cost of twenty-five square yards of solar heating-surface be $225 (the rate of cost of the Athenæum surface), and interest be counted at five per cent, and repairs at three per cent, the cost of solar heating would be nearly $18 for the same quantity of heat yielded by a ton of coal, or $10, if the first cost of the surface were reduced to $125 (the lowest rate of cost of construction given by builders). This estimate makes no account of the heat which the uncovered wall would absorb, and in part transmit, by conduction, through the wall to the maintenance of inside warmth.

The second part of Mr. Woodbridge's paper referred to the effect enveloping a building in glass may have in retaining its heat, his estimate having been made with reference to the new building. The ratio of heat-loss through equal areas of 18″ brick wall and single glass is 1 to 4. The ratio of area of total wall to total window is 22 to 12. The ratio of loss through wall-area to that through window-area is, therefore, 22 to 48. The saving effected by glass over glass is one-half that otherwise lost through single glass, and the saving by glass over brick is one-fifth. The ratio of actual saving per equal areas is, therefore, brick 0.2, and window 2, and the saving for the

actual areas of brick and glass would be, for brick 4.4 to glass 24, or six times as much would be saved by covering 12,000 square feet of window by glass as by covering 22,000 square feet of brick in the same way. The ratio of saving in coal by a glass envelope surrounding the building would be, wall $60 to window $305. But the ratio of cost in interest and repairs would be, on the lowest estimate furnished by competent builders, wall $475 to window $261. By double-glazing the windows the same gain in heat saved could be had at the low cost of $80. Thus, the loss of glass covering the walls would be $415, and the gain in double-glazing the windows would be $225 per year. Under the most favorable conditions of southern exposure, the southern wall of the building (brick surface alone considered) would, if supplied with the solar heating surface, yield, by solar heat acquired, a saving of $95, and by heat retained $16, making a total of $111 per year, while the cost of the surface maintenance would be $197.

The conclusion of investigations, as far as carried by Mr. Woodbridge, he stated to be adverse to the commercial value of the method proposed by Prof. Morse, and that as the question of cost largely controls the choice of means, solar auxiliary heating is likely to receive less favor than it deserves on the ground of its hygienic worth.

MEETING 339.

Application of an Electrical System of Propulsion on Elevated Railroads.

BY LIEUT. F. J. SPRAGUE.

The 339th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Dec. 10th, at 8 P. M., Hon. J. A. Dresser in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Lieut. F. J. Sprague, of New York, who read a paper on the "Application of an Electrical System of Propulsion on Elevated Railroads."

Lieut. SPRAGUE said: The necessity for additional means for rapid transportation in New York is most urgent. In considering how the capacity of the roads may be increased, it is necessary to note the character of the roads and their method of operation, and, for that purpose, we will take the Third Avenue line as an example. This is about eight and a half miles in length, the grades varying from eight to one hundred and five feet to the mile, with about one-third of the distance level. In the seventeen miles of single track there are fifty-two stations. Hence, three times in every mile, on an average, a train has to start a weight oftentimes as great as ninety tons from a dead rest, raise it up to a speed of nearly twenty miles an hour, propel a short distance at that speed, overcome not only the inertia of the train and the traction which is required for the train on a level, but also climb grades, and then suddenly bring the train to a rest. All this must be done in one and one quarter minutes.

The mean traction of the locomotives is four times that necessary to draw the train at its mean speed of fifteen miles an hour on a level, and in getting under way, and climbing the one hundred and five foot grades, the traction is at least ten times this amount. The acceleration of the train on the down grades, and the momentum stored up in the train in getting under way, play but little part, except on the down grades, in propelling the train, because the stoppages are so frequent, and at such short intervals, that advantage cannot be taken of any of this stored-up energy. Hence, a large proportion of this is thrown away. With cars of a seating capacity of forty-eight, and room to accommodate forty more standing, it is evident that the capacity of each car of the train cannot well be increased, and the capacity of the trains can only be increased by increasing the number of cars. There are already sixty-three trains in operation at one time on this road during commission hours; they run at very close intervals, and they must be under the most perfect control. Every car added increases the momentum of the train, rendering it more difficult to quickly and efficiently check the speed, and increasing the liability of, and danger from, any derangement of the brake apparatus, especially where dependent upon one source. If the length of the trains be increased,—admitting that they can be handled without difficulty,— the engines will be forced to a duty much beyond that for which they were constructed.

Furthermore, when the tracks are in a slippery condition, the weight of the engines does not give sufficient tractive power to promptly get away from the stations. An additional car will render this delay more frequent, and tend to reduce the traffic-miles per hour run during commission hours.

To get increased traction in the present system it is absolutely necessary to increase the weight of the locomotives, but such increase of weight is useless unless it be effective on the drivers; but if effective on the drivers, then we have an increased dead weight applied to the superstructure of the road at one point Therefore, since the shearing safety-limit of the superstructure has been nearly reached, it would be very unwise to increase the capacity of the road by increasing the weight of the locomotives.

Two ways, however, remain by which the capacity of the roads can be increased: one, by increasing the number of cars in a train, provided it can be done without increasing the weight of the tractive power, or if it can be distributed and the train remain under absolute control; another, by increasing the mean running speed.

Increasing the length of the train will not produce any very much greater strain on the structure, because the columns are only forty-three feet apart, and the cars about forty-six feet long, so that the weight of a dozen cars would not increase the shearing or tensile strain beyond that due to two cars.

To get a higher speed of the trains it is probably necessary to increase the power, and, at the same time, to increase the traction. This increased traction, however, must be distributed; it cannot be put at any one point. It is not practicable to increase the number of trains materially, because they run as closely as can be with safety.

We see, then, that steam-locomotion does not present many opportunities to better the conditions of the road. Hence, we are obliged to turn to some other method, and that which promises the most satisfactory solution is an electrical system.

I have for a long time been elaborating such a one, and am now convinced that this is the future method of propulsion for the trains of the elevated roads, and it is a near future.

In the substitution of one system for the other, what is the object sought? Ultimately, of course, it is a greater return for a given investment, and it is to be obtained in one or more of three ways:

First. By decreasing the coal expended per passenger carried, if this is practicable.

Second. By reducing the wear and tear of the motive power, but more particularly that of the road-bed.

Third. By increasing the carrying capacity of the roads.

The saving of labor I do not think one of the objects to be particularly striven for, the handling of passengers and trains probably never requiring a less number than are now necessary.

It is evident that if any decrease in the wear and tear of the superstructure can be accomplished a great saving will result. By a system of electrical propulsion the power can be distributed underneath the cars,—every car, or two cars if need be, being a unit,—and at the same time arrangements can be made for propelling five or six cars under simultaneous control. By distributing the power under the car, the whole weight of the car and passengers can be made effective for traction, such traction-weight being six times as great as is afforded by the present locomotives. This will enable the cars to be started more promptly, brought to speed more quickly, and stopped in shorter intervals, increasing the mean rate of speed, and thereby the capacity of the road.

Weight is the necessary practical adjunct for traction. The elevated roads present a peculiar problem. To attempt to solve it by replacing the present locomotives by electric locomotives of lighter weight, or even of the same weight, is to shut our eyes to plain mechanical and engineering truths, and does not advance by one single step such solution. The making of cars individual units of locomotion will enable the intervals between trains to be made one-third those of the present schedule for a large part of the time. This would greatly increase the number of passengers during the day and night who would make use of the elevated roads, and this, too, without materially increasing the running expenses.

Another important advantage will be the great reduction in the vibration and wear and tear of the superstructure by distributing the weight so much more evenly. The weight upon the lattice-girders between columns would always be less than two-thirds, sometimes only one-third that now existing, the vibration, tensile, and shearing strains being nearly in the same proportion. The motive power being rotary, the train would start more smoothly, and the motive power be

less liable to derangement; slipping or skidding, such as is now common both in starting and stopping, would be unknown. [The speaker then showed by a series of mathematical demonstrations the power actually developed on the Third Avenue line during commission hours as follows: He divided the work of engines into three parts; first, that necessary to overcome the train's inertia; second, the work of lifting train from level of low to that of high grade; third, the work of traction. The train consisting of four loaded cars of twenty tons each. The energy required in overcoming inertia alone in getting under way at each station is 2,105,400 ft. lbs., or total energy per round trip, 114,972,000 ft. lbs. Total work of lifting the train per round trip is 47,355,000 ft. lbs. Total work of traction per round trip is 32,472,000 ft. lbs. Total work per round trip is 194,799,000 ft. lbs. The time for round trip being eighty-four minutes, the average horse-power is 70.3, and, at the busiest time, when sixty-three trains are in operation, the total power developed in motors at one time is 4429 H. P., to which add five per cent for friction gives 4650 H. P. He also showed that the coal expense is only $1.15 per round trip, an average of 2⅕ cents per station. One passenger at every other station, during commission hours, would pay the coal expenses of the trip. Also, that during commission hours, for the same gross weight moved, the electrical train will carry fifty more passengers than the steam-train, or, for sixty-three trains, 3150 through passengers — or double that number of way-passengers — at one time.] The speaker then went on: A steam-locomotive, of the type considered, has 30,000 lbs. weight on the drivers, hence its tractive weight is fifteen tons.

An electrical train having the motive power distributed has an effective tractive weight of eighty tons, or twenty tons per car. In an electrical system such as I have devised, a large proportion of the energy of the trains is recovered when slowing to stops and on down grades. This is accomplished by a method of breaking which consists of being able at will to convert the energy of the moving train into electrical energy and deliver it to the line, and by the same apparatus which controls the speed and power of the train. On a double-track road the energy given to one track may be communicated to the other as well as along itself. The up grades of one track are balanced by the down grades on the other track. Therefore, energy being expended in getting under way and climbing up grades, and a large

proportion of this being given back in stopping and running on down grades, it is evident that the energy required in the system is that necessary to move the trains continuously on level grades with a percentage for loss of reconversion added. This is one of the very great advantages of an electric railroad, where grades and stoppages are frequent, and a large number of trains operated. By this method referred to, it is an easy matter to reduce the speed of a train to a third or fourth of its maximum, the breaking-power being under perfect control. If, say, to one-third speed, then since the energy of a moving body is proportional to the square of its velocity, eight-ninths of the train-energy is available for the first step of breaking; that is, $\frac{8}{9} \times 2{,}105{,}400$ ft. $= 1{,}871{,}400$ ft. lbs. At least seventy-five per cent of this will appear as current delivered back to the line, or in one round trip there will be saved 72,976,800 ft. lbs., of which eighty per cent will appear as effective tractive work again on the axles; that is, it relieves the main generating station of the supply of 58,381,400 ft. lbs. of energy. Also, seventy-five per cent of all the energy of falling, in excess of traction, will appear in the form of current, of which eighty per cent will become effective for tractive power. This amounts to 17,028,000 ft. lbs., which, added to 58,381,400, gives 75,409,400 ft. lbs. of effective work recovered. This, subtracted from the total work per round trip — 194,799,000 — leaves 19,390,600 ft. lbs. net power expended per round trip, an average of 43 H. P. per minute, or a total of 2710 H. P. for sixty-three trains.

This is the net effective power at the trains which is required to operate sixty-three trains of eighty tons each, as against 4650 H. P. in the present steam-plant, a difference of 1925 H. P., or forty-one per cent in favor of this system.

But the electrical power must be generated at one or more central stations, transmitted to the motors, and then reconverted into mechanical work,— the original mechanical work of the engine suffering from two conversions and one transmission. Experience shows that, with a good distribution and properly-constructed motors, sixty per cent of the original will appear as effective work on the car axle. Then for any electrical system not using the Sprague system of breaking, but with other losses the same, there will be required at the central station $\frac{100}{60} \times 4429 = 7382$ H. P.

With the Sprague system nearly every motor coming to a station

or running on a down grade becomes a generator which is helping to supply the current needed to operate the remaining trains.

This method has already been shown to save about forty per cent as against any other electrical system.

Again, instead of the current being all supplied by the main generating station at one or two points, it is supplied from nearly as many moving stations as there are trains slowing down or running on down grades. With any given size of conductors and average potentials this would greatly reduce the loss, or, with the same percentage of loss on line, the main conductor would be very much smaller, because less current is supplied from the central station, and it is transmitted a shorter distance. The relative size of conductors necessary would be about as one hundred to forty-five, a saving of fifty-five per cent in favor of this system. In the Sprague system there would be required at the central station $\frac{100}{60} \times 2710 = 4520$ H. P., something less than that developed on the present locomotives, which is 4650 H. P. That is, the losses of two conversions and one transmission is more than counterbalanced by the amount saved in this system of breaking.

The present engines have to use a good grade of coal, which costs, ready for use, $4.00 per ton. The duty of these engines is about six pounds of coal per horse-power per hour. Large stationary engines can be relied upon to develop horse-power per hour on three pounds of a lower grade of coal, such as a mixture of anthracite dust and bituminous coal, which can be delivered to the furnaces for $2.50 per ton. The ratio of expenditure for coal would be found as follows: $\frac{4650}{4520} \times \frac{6.00}{3.00} \times \frac{4.00}{2.50} = 3.30$; that is, for every $3.30 spent for coal in the present steam-plant, there would be expended $1.00 in the Sprague system, a saving of about seventy per cent. Against this, and some present labor expenses, must be put the cost of running the central stations.

Another consideration — which must be taken into account when a part of the energy of the trains is returned to the lines, as I have described — is the great saving in the original investment at the central stations as well as in the conductors. In the particular instance here given there is a difference in the power to be provided for at the central stations of $7382 - 4520 = 2862$ H. P. The saving on this would, for lots, buildings, boilers, engines, dynamos, and fittings, be

not less than about $150 per H. P., or $429,C00. There is nearly a proportional saving in the labor, depreciation, and the incidental expenses of the central station. Again, since the motor system affords a very perfect system of breaking, neither vacuum nor pressure brakes need be used, although the hand brakes would, of course, be retained.

As a somewhat remarkable corroboration of theoretical by practical work, I would refer to the account of Mr. Angus Sinclair's work in the *Scientific American* (Supplement of October 3d). Through the courtesy of Col. Hain, Manager of the Manhattan Road, Mr. Sinclair, assisted by Mr. J. D. Campbell, general foreman of the Elevated Railroad machine-shops, made a very thorough test of the capacity and performance of one of the standard engines on regular duty. The engine was indicated for two round trips; that is, over a run of about thirty-four miles, and all other necessary data taken. The average power used during the whole distance was 77.8, ten per cent of which is allowed for friction of the engine, leaving net 70 H. P. This by actual experiment.

By theoretical determination I get 70.3 H. P., which includes five per cent friction, or a net of 67 H. P. The difference is 3 H. P., or $4\frac{1}{8}$ per cent, which may represent the excess of weight of the trains tested.

I have presented these facts about the present and future of the elevated roads of New York for your consideration, not because you are particularly interested in New York, but because the problem of rapid transit in Boston has become one of the urgent needs of the present. As the elevated roads there met with great opposition, so has the project of reaching the suburbs of Boston roused a host of objectors. The reasons for this are in part sound. Your streets are, many of them, narrow and crooked. Property owners along the route object to a double-track system of roads extending the full width of a street, to the noise, the steam, the water, the oil, the vibrations, the dirt and cinders incident to a steam system.

But the elevated roads of New York were projected some years ago. Active minds of engineers and inventors have worked out improved methods of construction for the special needs of cities like Boston, where trains may be required to go by one street and return by another. Such roads can be built, the structure of which will not take up as much room in the streets, and will not obstruct the air and

light over one-half as much, as the New York roads, and I feel confident they can be built for less money. With electric propulsion you can have rapid and smooth-running trains of one, two, or more car units. The strain on the structure being much less than in a steam-plant, the whole structure can be made lighter in the same proportion. Dust, smoke, cinders, oil, and water will disappear. Power will cost less. Trains can be run at shorter intervals, and under more perfect control. The energy of the train will become available for the purpose of braking. Repairs of superstructure will be less. In short, electric propulsion, more than any other thing, will make practicable for Boston what it has so long and so sadly needed, — rapid transit to its suburbs. I need hardly point out to you the increase in the value of this property which will more than pay the cost of the roads.

After some discussion the meeting closed with a vote of thanks to Lieut. Sprague for his very interesting paper.

MEETING 340.

The Pneumatic Dynamite Gun, and the Use of High Explosives in Warfare.

BY LIEUT. E. L. ZALINSKI, U. S. A.

The 340th meeting of the SOCIETY OF ARTS was held at the Institute on Wednesday, Dec. 23rd, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the President introduced Lieut. E. L. Zalinski, U. S. A., who read a paper on "The Pneumatic Dynamite Gun, and the Use of High Explosives in Warfare," illustrated with numerous views shown on the screen.

Lieut. ZALINSKI said: The first pneumatic gun presented for experiment by Mr. Mefford, the first designer, consisted substantially of a brass tube two inches in diameter, one-quarter inch thick, and

FIG. 2.—ZALINSKI'S 2-INCH AIR-GUN.

twenty-eight feet in length, placed in a T rail, stiffened by tie rods, and mounted on a tripod. (See Fig. 2.) It was arranged for breech loading. The tube was connected with an air reservoir by means of a flexible hose. Air was admitted from the reservoir by means of an ordinary cock worked by hand.

The projectiles were cylindrical brass tubes about one and one half inches in diameter, and from twelve to eighteen inches in length, with a wooden frustum of a cone attached, the larger end being the diameter of the bore. The points were wooden plugs, leaded to throw the center of gravity well forward. The results obtained were surprising. At a range of over eight hundred yards the missiles were driven into pine blocks from sixteen to twenty-four inches, and with less than five hundred pounds pressure shells were thrown twenty-one hundred yards. The firing showed greater accuracy than ordinarily obtainable with smooth-bore guns.

Here was an extreme example of the most recent line of development in ballistics, *i. e.*, slower powders giving much lower pressures, but burnt in longer bores, and thus imparting, eventually, higher velocities than previously obtainable.

The maximum length of powder guns is thirty-five caliber. This gun is one hundred and sixty-eight caliber long, and, in consequence of its greater proportional length, and the fact that the pressure is maintained throughout the whole length, while it falls rapidly in powder guns, an energy may be imparted to the projectile nearly approaching that of powder guns. This, too, without subjecting the projectile and its contained charge of explosive, if a shell, to any pressure that might produce premature explosion. A gun of four-inch diameter of bore, and forty feet long, was next built. The valve was automatic in its action. It was required to open rapidly, permit a certain uniform volume of air to escape, and close about the time of the arrival of the projectile near the muzzle of the tube. It might be considered either as a time-valve or an air-meter. The projectiles were made with the center of gravity as far forward as possible, as experiment has shown that, so constructed, they will be much steadier in their flight and the range more nearly uniform. In the first experiments ordinary percussion-fuses of fulminate, placed in the point of the conical head of the shell, were used to explode the charge, but they did not act uniformly, and many failed to work at all. Next,

copper capsules of fulminate were used with similar results. A noticeable fact was that shell, charged with seventeen pounds of dynamite, having the percussion-capsule in front, upon striking and exploding sometimes produced comparatively slight effects. I account for this on the assumption that time is required for the explosion of the entire charge; that the gases evolved by the explosion of the layers in immediate contact with the target tended to throw back the gases afterward evolved from the portions of the charge in the rear. It therefore appeared desirable to make the initial point of explosion at the rear point of the charge, and, to prevent an explosion at the point from simple impact, the explosion must take place an instant before the body of the projectile had actually struck the target. To do this I devised an electrical fuse, which could be placed at any point within the charge, and, while not abnormally sensitive to shock while in the bore of the gun, would act upon the slightest touch when striking the target. This consisted of a chloride of silvery battery with suitable circuit arrangements and electrical primers. A very small battery suffices to give a current which would bring the platinum wire-bridge of the fuse to a red heat, and insure the ignition of the charge.

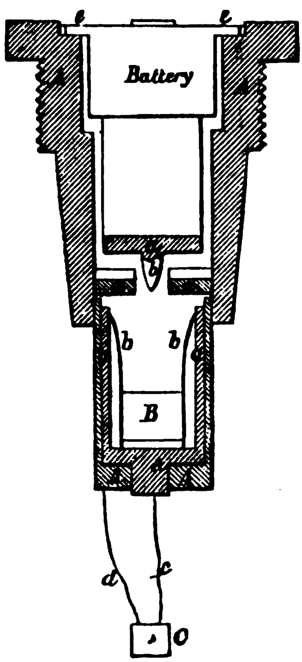


FIG. 3.

The diagram, Fig. 3, is a section of the fuse and connections, in which A is the fuse case, B a metallic plunger, inside the vulcanite cylinder *a*; the contact springs *b b* are attached to the wire *c*, joining the electrical primer C. The second wire *d* goes from the primer to the metallic fuse case. The primer is thus in contact with one pole of the battery placed within the upper part of the fuse case. As will be seen, this battery is suspended to the fuse case A A by thin projections *e e*, which are

sheared off by the shock of firing the gun, and the other pole falls into such a position that the metallic plunger B can come into contact with it and complete the circuit. When the shell strikes, the plunger B moves forward to the pole *f*, the circuit is closed, and the charge is exploded.

To determine the best details of arrangement of the charge and fuse, the following experiments were made: —

A blank shell filled with sand, total weight thirty pounds, was fired at a range of sixty yards. It penetrated three plates aggregating 2.5 inches. A similar shell charged with dynamite, having a fuse intended to explode on impact, penetrated only a single plate, and its effect was actually less than that of the blank shot. Another shell fired with a detonating fuse in the front did but little more damage. An electrical fuse was then arranged so that the circuit should be closed when the body of the shell was one-eighth of an inch from the target, the primer being placed at the rear part of the charge. The resulting explosion was the most effective produced, the six plates of the target, aggregating 4.5 inches in thickness, being broken through and indented in a circular area of about eighteen inches diameter. From these and other experiments it was evident that the effects of the explosion would not be limited to simply penetrating the target, but it would produce cracks and breaks at a considerable distance from the point of impact.

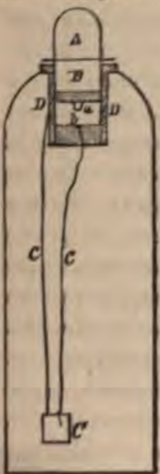


FIG. 4

By examining the diagram, Fig. 4, it will be seen that in the fuse just mentioned the battery was attached to a projecting steel plunger, held in place by a stiff steel wire pin, and when the end of the plunger was within one-eighth inch of the target, the circuit was closed. In this diagram, A is the steel plunger, and B the battery attached to it; C is a low-tension electrical primer, one wire from which, *c*, goes to a contact *b* in the bottom of the fuse; the other connects the primer and the fuse case. On striking the target, the plungers are forced in, shearing off the light steel safety pin; and, when the front of the shell is at the desired distance from the tar-

get, the pole a of the battery comes in contact with b, and the circuit is closed through the primer, which explodes the charge from the rear. The actual time required to produce explosion before the full impact of the shell took place was $\frac{1}{1000}$th of a second. Plungers arranged to close up to a quarter of an inch from the target were successful, but beyond that the effects were weakened.

An eight-inch gun was designed and built while these experiments were in progress. The charge to be thrown was to be at least one hundred pounds, the initial velocity approaching that of the eight-inch powder gun, *i. e.*, about fourteen hundred feet per second, and a range of about two miles (the extreme range of the largest movable torpedoes, such as the Sim's electrical torpedoes). The mechanism was such as to enable one man, the person sighting, to train the gun, elevate and fire it, without moving his eye from the sight. The mathematical details of the gun were designed by Mr. Nathaniel Pratt, mechanical engineer of the Babcock & Wilcox Company.

To accomplish the desired result with the pressure fixed upon — two thousand pounds per square inch — it was necessary to make the barrel sixty feet long.

The gun has, thus far, been worked with only one thousand pounds pressure, yet, with an elevation of 35°, a shell carrying a sixty-pound charge has attained a range of two and a quarter miles, and one containing one hundred pounds a range of three thousand yards with 33° elevation.

Having described the machine for projecting a shell charged with high explosives, the question naturally presents itself as to what the effects of the explosion will be. Both confinement and a detonation are required to afford an explosion of the first order. The less sensitive the explosive to shock, the more powerful must be the detonation to produce the maximum results.

Fulminate of mercury appears to be the most powerful detonator, but it is more sensitive to shock than any of the high explosives, so that, if it is desired to throw any of the high explosives, they must be accompanied by a detonator to whose greater sensitiveness the shock of propulsion must be tempered, or premature explosion ensues. Simple heat does not produce explosion, as with gunpowder. The explosives, instead of flashing as gunpowder does, burn comparatively

FIG. 5. — ZALINSKI'S 8-INCH AIR-GUN.

quietly for some time, and, unless the mass is considerable, there will be no explosion. On the other hand, heating the explosives, even to a comparatively low degree, makes them abnormally sensitive to explosion by concussion.

The relative force of the high explosives appears to be difficult to state, as definite measurements cannot well be made except for small quantities, and I believe that this does not indicate their nature when properly exploded in large quantities.

The most definite values of the relative force of high explosives have been determined by Gen. Abbot, Corps of Engineers, U. S. A., to be as follows, dynamite No. 1 being taken as the standard at 100:

Nitro-glycerine,	81
Compressed or granulated gun-cotton,	87
Rackarock (best formula),	104
Atlas powder (grade A),	100
Forcite gelatine,	133
Explosive gelatine (4 per cent camphor),	117
" " (without camphor),	142

Gen. Abbot concluded, as the result of his experiments, that an instantaneous pressure of sixty-five hundred pounds per square inch can be adopted as the measure of a fatal shock to a first-class ship-of-war. In these experiments eighteen inches of water was used in tamping. [The speaker then described several experiments of dynamite exploded in superficial contact with iron plates, the effects in each case being very slight.] But neither the tamping of eighteen inches of water or explosion in superficial contact can represent the existing conditions when the shell, charged with one hundred pounds of gelatine, comes in contact with the enemy's armoring. It is not proposed to simply send the shell with just sufficient force to place it in superficial contact, but to send it there with a remaining energy, upon striking, of several hundred foot tons, which must doubtless serve as a very effective tamping.

According to a formula deduced from some Scandinavian experiments, one hundred pounds of explosive gelatine will perforate about 6.5 inches of armor. But the decks of the most heavily-armored ships are not over four inches in thickness, and usually less, so that this, certainly, is vulnerable to a shell containing a one-hundred pound

charge; and the deck of a vessel presents, by far, the greater portion of the target subject to fire. Again, granting that failure to perforate the heavier armor may ensue, yet the concussion and shock will doubtless be felt in the disarrangement of the machinery and breaking of weaker parts some distance from the point of impact, not to speak of the physical effects of the enormous shock upon the crew in the vicinity. Failing to strike the ship, the dynamite shells are now arranged so as to explode after they are entirely submerged in the water. Here an explosion anywhere within twenty-one feet would be fatal according to Gen. Abbot's formula.

This adds a very large area of vulnerable parts to that of the already large area of the deck. Even if exploded at a greater distance than twenty-one feet, up to about thirty-five feet, the effect would probably be injurious to the propelling machinery, and practically paralyze the ship.

In order to safely propel charges of the high explosives against the submerged portions of an enemy's ship, a number of complicated and expensive propelling-torpedoes have been devised. The one most generally used is the Whitehead fish-torpedo. It has a maximum range of eight hundred yards, while two hundred yards is the greatest distance for certainty of action. Its speed is twenty-seven knots per hour.

The extreme range of the Lay torpedo is two miles, and the mean speed about twenty knots. It is steered and fired by means of a connecting cable.

The Sim's electrical fish-torpedo is propelled by electricity from a dynamo on shore or on shipboard, and is steered from there. This is entirely submerged and kept at the desired depth by means of a float which maintains its buoyancy even after it has been repeatedly perforated. But, on account of having to drag this large float, the speed is very slow. The largest one yet constructed has a range of two miles, with a speed of about eleven knots. This, as well as the Lay torpedo, has to be seen throughout its course to strike the enemy, which is a matter of no little difficulty when the water is rough. All the moveable torpedoes have the common disadvantage that they can be stopped by netting properly placed, and if expended without effect, a considerable plant has been lost.

The torpedo shells projected by the pneumatic torpedo-gun can

attain a range of two miles in twenty-two seconds, and they can be directed against the enemy much more accurately than appears possible with the others. If it misses the target, the only expenditure is the shell and its charge. Placed, for defence of harbors, within fortifications, they can be brought into use at a time when the enemy's fleet comes to close quarters,— that is, within two miles, the present effective range of the gun. They could be placed on board swift-moving torpedo-boats, which could approach a beleaguering fleet, at dusk or at night, within a mile, and deliver a most damaging fire. Where the enemy has succeeded in removing existing torpedo-obstructions, these machines can shower its pathway with torpedoes which, when the depth is suitable — say fifty to sixty feet or less — can be arranged to explode either directly upon reaching the bottom or at any desired interval. On the other hand, in making an attack in a port, torpedo-boats, armed with the pneumatic gun, could strew the channel, through which the fleet is to advance, with the torpedo-shells, arranged to explode, some, soon after reaching the bottom; others, when fully submerged. These, if dropped at short intervals, would inevitably break up any system of torpedoes which can be planted.

In warding off the attack on a ship by any of the movable torpedoes, if they should be discovered approaching, I can think of nothing which has so many chances of success as the torpedo-shell projected from the pneumatic gun.

A vote of thanks to the speaker brought the meeting to a close.

MEETING 341.

Late Methods of Drilling for Oil and Natural Gas.

BY MR. F. H. NEWELL.

The 341st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 7th, at 8 P. M., Prof. L. M. Norton in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Mr. F. H. Newell, who read a paper on "Late Methods of Drilling for Oil and Natual Gas."

Mr. NEWELL said: The problem which the would-be producer of crude oil, or natural gas, has before him is something like this: At an average depth of about fifteen hundred feet there probably is a stratum of sandstone, which, though quite compact and well cemented, holds in the interstices, between its grains, oil or gas, probably existing as a fluid, under enormous pressure.

To reach this store of oil he must penetrate, first, the surface soils and drifts, which vary in depth from a few inches on the hills to four hundred and fifty feet in the valleys; then, below these unconsolidated deposits, the more or less firm strata of the coal measures, or upper Devonian, lying horizontally, and consisting mainly of shale with beds of sandstone and occasionally conglomerate interstratified in every variation of order and thickness. The surface deposits of gravel and clays are saturated with fresh water, as is also, as a rule, the consolidated rock near the surface. Below the fresh-water bearing strata are found, occasionally, layers full of salt water, and usually below these the shales, even for a thickness of a thousand feet, are completely dry until the oil-bearing sondstone is reached.

It is probable that the permeability of the oil-bearing sandstone, and therefore its ability to deliver oil into the well, is injured by these surface waters entering the sandstone, and the pressure of this fluid, standing in the well, interferes with the free movement of oil towards the hole. Therefore, the completion of an oil or gas well requires the successful performance of at least three operations: making the well-hole through soil and rock, preserving its shape by pipe through unconsolidated gravels and soft rocks, and the exclusion of water.

There have been suggested several ways of sinking wells: first, the one in use since time immemorial, *i. e.*, digging. This method has actually been tried; oil-shafts have been sunk, not only in the Old World but in the oil-fields of Pennsylvania and Ohio; and it is a significant fact that of these shafts none, as yet reported, have yielded a larger amount of oil per day than the small drill-hole made in advance, though the drill-holes were only five inches in diameter, and the shafts at least five feet, thus exposing at least twelve times as much wall surface. Hence economy dictates that the well should be made as small as possible. To do this a diamond-drill might be used, but as a fact, this machine, though so useful in inclined strata, or where it is desired to bore in other directions than the vertical, or

where exact samples of the rocks passed through are of first importance, cannot compete in cost with the cruder methods in present use. The method in almost universal use is drilling by walking-beam and rope, but it must be remembered that this way of drilling is only applicable in comparatively soft rocks, such as limestones, shales, sandstones, and moderately well-cemented conglomerates, where they are horizontally bedded and unfissured, for the drill, guided largely by its own weight, is easily deflected by inclined bedding, cracks, or planes of weakness, and, once turned from the exact vertical, soon binds and refuses to work, and the hole is straightened only after considerable delay and expense. The art of drilling has grown, by the inventions and discoveries by hundreds of men, from one very simple operation to a business using in special cases an almost innumerable variety of tools, and having large establishments to make its peculiar machinery.

The growth of this specialized industry of making drilling-tools has been accompanied by the adoption of certain standards of sizes of tools and machinery, as also of hole and material inserted, so that at the present time and for some years past all wells are, and have been, drilled of the same size.

Some of the principal considerations which governed the choice of a certain diameter of well are: the smaller the hole the less iron is used in casing; also less material must be removed, thus faster time can be made, the same weight of tools being used. But, on the other hand, the smaller the hole the longer the drill must be to give the necessary weight. It eventually becomes too long for strength or convenience in handling, and, as a compromise between these, the diameter of five and a half inches has been adopted, so that now there are probably over twelve thousand wells of this diameter, ranging in depth from six hundred to two thousand feet.

The principle of ordinary drilling is very simple, the operation being but the employment of machinery to lift and let fall a heavy drill. The drill is suspended from a rope attached to the end of an oscillating walking-beam, at each stroke being turned, so that it may cut a round hole.

When the fine sand and mud, made by the constant pounding of the rock, has accumulated so as to interfere with rapid cutting, the drill is taken out, water is poured into the hole, if not already there,

so as to form a very fluid mud, which then can be bailed or pumped out. The drill is then put back, the operations of drilling and pumping being alternated for every five feet of advance.

The drill is composed of several parts, viz., the bit, stem, jars, sinker-bar, and rope-socket, screwed together with tapering steel joints, and weighing in all about twenty-two hundred pounds. The bit is three and one half feet long, and weighs about one hundred and forty pounds. Its steel point is dressed to an obtuse cutting-edge to fit into a circular guage five and five-eighths inches in diameter, so as to insure its cutting a round hole. Bits were formerly made tapering, and dressed like a cold-chisel, a circular reamer being used at intervals to true the hole. The stem is three and a half inches in diameter, and usually thirty-two feet long, but sometimes fifty feet long. It weighs about twelve hundred pounds.

The jars consist of two interlocking slotted pieces, having a longitudinal play of nine inches. When the bit is stuck the top piece slides down, and then is pulled up, giving a sharp upward blow, rapidly repeated, thus loosening the bit, when it could not have been started by a direct pull on the cable.

The sinker-bar is twelve feet long, and weighs four hundred pounds. Its use is to give greater efficiency to the blow in loosening the bit. The cable on which the drill is hung extends up above the surface of the ground, and is held while drilling by clamps, which can be lowered as the drill advances by a device called the "temper-screw," suspended from the end of the walking-beam. The bailer is four inches in diameter, and about twenty feet long, made of thin galvanized iron, with a cone valve in the bottom.

The wood-work and moving parts making up the machinery for handling the tools is included in the term "rig," of which the most important object is the derrick. This is seventy-two feet high, twenty feet square at the base, and three feet square at the top. Its object is to carry a pulley to a sufficient hight to swing the tools when taken out of the hole. It is built of two-inch plank, cross-braced by boards. The heavy foundation-timbers of derrick and machinery are all gained and keyed together, so that all parts can be quickly lined up or tightened. No masonry is used in any part.

In beginning a well in the valleys where the loose earth is of great thickness, the important and expensive operation of keeping this

in place is performed by driving pipe. This pipe is an extra thick lap-weld tube eight inches in diameter; the lower end of the first joint is armed with a steel shoe, shrunk on. It is driven by a log used as a maul, much as piles are driven, guides for which are set up in the derrick, and length after length being screwed on and driven down until bed-rock is reached. To facilitate driving, an eight-inch bit is put inside, drilling out the gravel and dirt, and keeping ahead to break any boulders or hard strata, so that the drive-pipe shall not be deflected.

When the drive-pipe is set, the eight-inch hole is continued below the water-bearing rocks, and casing five and five-eighths inches internal diameter is put in, shutting off the water. Then the ordinary five-and-a-half inch bit is used, and drilling goes on until the oil or gas-bearing rock is reached.

It is customary to torpedo a well as soon as drilled through the oil-bearing sandstones, in order to open fissures in the stone, and thus increase the flow. For this purpose nitro-glycerine is used in quantities up to two hundred quarts, or six hundred and sixty pounds, at a time, a good charge being one hundred quarts, costing, exploded in the well, $1 per quart. It is placed in tin cases four inches in diameter, and about eight feet long, which are lowered, one at a time, the last one carrying a firing-head containing ordinary waterproof percussion-caps. The torpedo is exploded by dropping a weight on the caps, or sometimes by a squib or time-fuse.

The flow of oil following the explosion is allowed to go into the air, that the well may be blown clear of loose stones, pieces of tin and iron, etc.; but immediately after this flow has ceased, the two-inch tubing is put in, and connections made with the tank, to save subsequent flows.

A large number of views were shown of the operations of drilling and shooting the well; of the "cities of tanks" at Olean and other places, belonging to the National Transit Company, whose total storage capacity is 42,000,000 barrels; of burning tanks, etc. These iron storage-tanks, which were described in detail by the speaker, were from eighty-five feet to ninety-five feet in diameter, holding from thirty thousand to thirty-five thousand barrels of oil each (forty-two gallons to a barrel). This was supplemented by remarks on the care of oil and gas wells, storage and transportation of oil, and the present

condition of the Northern oil-fields, concluding by a hasty reference to the geological structure of the country.

At the close of the paper, Mr. C. J. H. WOODBURY, on invitation of the chairman, spoke as follows: My experience with natural gas has been supplementary to the portion of the subject considered by the lecturer, inasmuch as my work has been confined to a consideration of its value in the industrial arts, as tending to its successful use, and also what measures will serve to render its use as safe as possible, avoiding in the future such sad accidents as have already wrought serious injuries to persons and property.

The supply from each gas-well will, no doubt, be exhausted in the near future, but the use of natural gas will undoubtedly be possible for some time to come, by reason of new wells.

Whichever of the several probable causes leading to the formation of natural gas be the true one, there is no doubt but that its production has ceased, and that the present supply is merely the draught from a limited reservoir. The use of natural gas has been attended with so many advantages that, irrespective of the supply, it is probable that the days of solid fuel for industrial metallurgy are substantially over. The saving of labor in handling coal, absence of deleterious impurities in gaseous fuel, high temperature of combustion, avoidance of fuel lost in starting or banking fires, all render the use of gaseous fuel a matter of great commercial importance. It has been represented to me that the gain of using natural gas in place of coal, in manufacture of wrought iron, amounted to $2.12 per ton, of which $1 represented the value of the increased quantity of wrought iron made from a given amount of pig iron, and $1.12 the saving in cost of labor and fuel. It is estimated that the increased profits to manufacturers in the Pittsburg district by reason of the use of natural gas amounts to $1,500,000 per annum; and if this be a fact, no one will begrudge the fifty per cent profit said to be made by those who have spent large sums in conducting the gas to the city, taking the risk of the speedy exhaustion of the supply.

Its use for stoves and fireplaces is quite general, the gas being fed from a perforated pipe, under a lot of broken crucible or fire-brick loosely thrown in where the coal is ordinarily placed. These pieces glow like an anthracite fire, with the pale blue hydrogen and marsh gas-flames playing through the interstices. A warmer effect is some- obtained by throwing some salt on the refractory pieces used in

the stove, and the yellow sodium-flame is their nearest approximation to a hickory fire. Being without smoke, the inside of these fireplaces is frequently white-washed.

The use of natural gas has not been without untoward incidents by way of numerous accidents, most of them of a serious nature; for it is odorless after being conducted a short distance in pipes, and explosive when mixed with between five and thirteen times its volume of air, differing in intensity, being a high explosive at its maximum, of one volume of gas to about 9.5 or 10 volumes of air.

It is very permeating, and, like hydrogen gas, leaks readily through joints perfectly tight against air, oil, or water. The most ingenious expedients have been devised to make tighter pipe-joints, and also conduct leaking gas away from the pipes to the atmosphere.

With these objects in view, it can be considered reasonably safe if the pressure is reduced, by a pressure governor, to less than one and a half pounds to the square inch; all pipes in yards or buildings should be above ground and away from concealed spaces in walls or floors; the fire should be applied before the gas is let on to a stove.

These rules may appear simple, but there will always be instances of their negligent infraction, rendering the matter of natural gas a live issue in underwriting as long as it is used, especially in houses.

Its candle power is eight and one half, and when burned through large burners gives a flaring yellowish flame, with a large blue center.

When carburetted with naphtha the illumination is better, but is exceedingly unsafe in case of leakage.

A vote of thanks was passed to the speaker, and the meeting was adjourned.

MEETING 342.

Transmission of Power by Belting.—An Account of the Work Done on this Subject in the Mechanical Engineering Laboratory.

BY PROF. GAETANO LANZA.

The 342nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 28th, at 8 P. M., Mr. Geo. L. Roberts in the chair.

After the reading of the minutes of the last meeting, and the

transaction of some business, the chairman introduced Prof. Gaetano Lanza, who read a paper on the "Transmission of Power by Belting.—An Account of the Work Done on this Subject in the Mechanical Engineering Laboratory."

Prof. LANZA said: It is well known to mechanical engineers that the rules for determining the proper width of leather belting, to carry a given power at a given speed, differ enormously from each other.

No better illustration of this fact can be given than the variety of rules given in the "Use of Belting," by John H. Cooper, a book that finds more or less favor among mechanics. In this book there are grouped together all the different rules that the author of the book could discover as being employed by any man who ever used a belt.

If we set out to compute, by means of a number of the rules heretofore in use, the proper width of belt to carry 30 H. P. when traveling 1500 feet per minute on a pair of 30″ pulleys, we shall obtain the following as the results:—

Webber's table,	12.″
Briggs & Towne,	13.″5
Cooper, page 28,	18.″8
" " 28,	21.″
" " 31,	22.″
" " 93,	22.″1
Sawyer,	24.″
Cooper, page 83,	27.″2
" " 112,	28.″0
" " 95,	30.″5
" " 32,	43.″2

The greater part of these rules are no better than guesses, being merely the practice of this or that mechanic, based upon no experimental evidence whatever. Rules of this character will not be considered in this paper, and only those will be discussed which have as their basis some experimental investigation, whether correct or incorrect; but even these differ in their results, in some cases, by as much as one hundred per cent.

During the last two years and a half we have been carrying on a series of experiments in the mechanical engineering laboratory of the Institute, with a view to solving this problem in such a manner as to leave no room for doubt as to the correctness of the results.

The work upon the subject has formed part of the regular laboratory work, and also the subject of two theses,—one by Mr. A. J. Purinton, and the other by Mr. A. L. Merrill.

Before giving an account of this work, and of the results obtained, I will state briefly what has been done by others.

The only experiments of which the writer is aware are the following:—

1°. By Gen. Morin.
2°. By Henry R. Towne, of the Yale & Towne Company.
3°. By Edward Sawyer, of Charlestown, Mass.
4°. By Samuel Webber, of Lawrence.
5°. By Prof. S. W. Holman, of the Mass. Institute of Technology.

(1°.) As to those of Morin, he used a fixed cast-iron drum, over which hung a belt, the ends hanging vertically, and being of equal lengths; these two ends he loaded with equal weights, and then added weight on one side until the belt slipped, and thus determined the two tensions T_1 on the tight side, and T_2 on the loose side. He then determined the co-efficient of friction f, from the formula—

$$f = \frac{\log._e T_1 - \log._e T_2}{\pi}$$

The results obtained by him are as follows:—

New belting on smooth cast-iron, dry, ...	0.284
New belting on smooth cast-iron, wet, ...	0.377
New belting on rough cast-iron, ...	0.281
Old belting on rough cast-iron, ...	0.279

He does not state what was the speed with which the belts slipped when he obtained these results.

(2°.) Mr. Henry R. Towne performed his experiments in the same way, only that he allowed his belts to slip at a speed as nearly 200 feet per minute as he could judge by the eye.

He obtained as a result $f = 0.58$; but he and Mr. Robert Briggs recommend for use two-thirds of this, or $f = 0.42$.

(3°.) Mr. Edward Sawyer, of Charlestown, used also a fixed drum, and performed the experiments in the same way as the other two, with this exception,—that, when he had loaded the heavy side sufficiently to make the belt slip, he then placed additional load on

the light side until he just stopped the slipping; then calculating his co-efficient of friction by the same formula, he obtained results varying from 0.12 to 0.17. Whichever of the three results given above is used, the rule for finding the ratio of the tensions on the tight and loose sides of a belt is given by the formula —

$$\frac{T_1}{T_2} = e^{f\theta}$$

where e = Napierian base, and θ = circular measure of arc of contact between the belt and the pulley; and, having this ratio, it is easy to compute the width of belt necessary to convey a given power at a given speed.

(4°.) As to Mr. Webber's experiments, there are only a few which were made to determine the ratio of tensions for 90°, 130°, 180°, and 270° arc of contact, with 18″, 24″, and 36″ pulleys; they were also made by letting the belt slide on a fixed drum, an auxiliary guide pulley being used to vary the arc of contact.

(5°.) In 1882 Prof. S. W. Holman, of the Physical Department of the Institute of Technology, undertook a set of experiments with a view to ascertain the cause of the enormous discrepancy in the results of the different experimenters. He caused the pulley to slide under the belt, hanging weights on the loose side of the belt, and attaching the other end to a spring-balance. He found that with a low speed of slip he obtained as low a result as 0.12, while with a speed of slip of 200 feet per minute he obtained about 0.58 and intermediate values, with intermediate speeds of slip; hence, that the co-efficient of friction varies with the speed of slip.

One important function of the Laboratory of Mechanical Engineering is to undertake and carry out original investigations of engineering problems. Recognizing, therefore, the importance of the belting problem, we set out to determine,—

1°. What is the average value of the speed of slip that we realize in practice under ordinary conditions of working?

2°. What is the co-efficient of friction that is obtained with this average speed of slip?

3°. How does the co-efficient of friction vary with the different kinds of belts and of pulleys. This research has been carried on as part of our regular laboratory work, and also in connection with the two theses already mentioned. A summary of the results obtained up

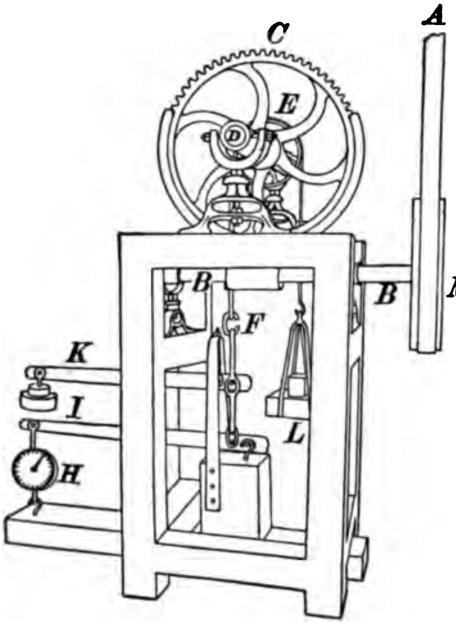
to the end of the last school year will now be given, but I will first describe the apparatus used and the manner of making the tests.

The slip tests were made entirely on 7-inch, 8-inch, and 10-inch double belts, by loading them with a known power by means of a nicely made Prony brake, on which the power used could be weighed. These tests were made as follows: Placing a fixed load on the brake, readings of counters attached to the driving and driven shafts were taken at definite intervals; and, the diameters of the pulleys being known, the slip of the belt was readily computed. The slip of these belts under ordinary loads was, on an average, about three feet per minute.

Experiments were then made upon a machine driven by power, and specially designed for the purpose, where a pulley was caused to slide under the belt at such a rate of speed as might be desired, and thus the ratio of tensions, and hence the co-efficient of friction under various speeds of slip, was determined.

The machine used for this purpose is shown in fig. 1. By means of the belt A and pulley M, the worm shaft B is set in motion, and, in its turn, drives the worm gear C, and hence the shaft D, and the pulley E which is fixed to the shaft.

FIG. 1.



The belt to be tested hangs over the pulley E, one end being attached by the link F to the lever I, the upward pull on this lever being registered by the dial H; at the other end of the belt is attached the scale pan L, in which are put weights. The lever K is merely a counterweighting lever.

During an experiment the motion is imparted in such a way as to turn the pulley *E* in a right-handed direction, the speed of a point on its circumference being the speed of slip of the pulley under the belt, the right-hand side of the belt being the loose, and the left-hand side the tight, side.

The tension on the loose side is evidently equal to the weight of the scale pan *L* plus the weights in the scale pan, while that on the tight side is read off on the dial *H*.

The average value of this co-efficient, under a speed of slip of three feet per minute, would seem to be, in the light of these tests, about 0.27, corresponding (if the admissible stress per inch of width be taken at 66⅔ lbs.) to the rule that a belt one inch wide must travel 1000 feet per minute to transmit one horse-power.

This requires much wider belts than Briggs' and Towne's rule to take 0.42 for co-efficient of friction; and, as a matter of fact, we never realize in practice, while driving, a slip anywhere near 200 feet per minute, which was the slip used in Mr. Towne's experiments.

I will next give the summaries: —

SUMMARY OF TESTS MADE IN 1883–84.

No. of Experiment.	Kind of Belt.	Side next Pulley.	Nature of Pulley.	Maximum Co-efficient of Friction.	Minimum Co-efficient of Friction.	Humidity.	Speed of Slip, in Feet, per Minute.
1	Old oak-tanned, .	Hair,	Lagged,	0.2700	0.2500	0.39	1.91
2	" " .	"	"	0.2730	0.2570	0.36	"
3	" " .	Flesh,	"	0.2660	0.2460	0.49	"
4	Raw hide, . . .	Hair,	"	1.0420	0.9825	0.44	"
5	" " . . .	Flesh,	"	0.5695	0.5250	0.44	"
6	" " . . .	Hair,	"	0.8800	0.8340	0.44	"
7	New oak-tanned,	"	"	0.2850	0.2620	0.38	"
8	" " .	Flesh,	"	0.2800	0.2640	0.39	"
9	Rubber, ...	–	"	0.3780	0.3450	0.39	"
10	"	–	Cast-iron,	0.3860	–	0.43	1.72
11	New oak-tanned,	Hair,	"	0.1440	–	0.48	1.91
12	" " .	Flesh,	"	0.1710	–	0.48	"
13	Raw hide, . . .	Hair,	"	0.2510	–	0.48	"
14	" " . . .	Flesh,	"	0.2650	–	0.48	"
15	" " . . .	Hair,	"	0.2260	–	0.55	"
16	Old oak-tanned, .	"	"	0.1560	–	0.55	1.95
17	" " .	Flesh,	"	0.1793	–	0.44	1.75

SUMMARY OF SLIP TESTS, 1884–85.

No. of Experiment.	Description of Belt.	Speed of Belt, in Feet, per Minute.	Horse-Power transmitted.	Speed of Slip, in Feet, per Minute.	Remarks.
1	10″ double belt, . .	1311	14.69	14.76	Inclined at about 45° to the horizon. The belt was very slack.
2	" " " . .	1350	11.12	9.64	
3	" " " . .	1365	10.23	7.13	
4	" " " . .	1385	8 31	5.75	
5	" " " . .	1414	5.31	3.57	
6	" " " . .	1411	5.31	3.34	
1	8″ double belt, . .	1537	14.69	10.98	Nearly vertical. The belt was very slack.
2	" " " . .	1586	11.12	7.49	
3	" " " . .	1605	10.23	6.52	
4	" " " . .	1630	8.31	4.61	
5	" " " . .	1666	5.31	2.70	
6	" " " . .	1664	5.31	2.14	
7	10″ double belt, . .	1315	8.88	4.33	The belt was now tightened to about ordinary tightness.
8	" " " . .	1303	11.75	5.41	
9	" " " . .	1298	12.66	3.12	
10	8″ double belt, . .	1597	6.11	1.53	The belt was now tightened to about ordinary tightness.
11	" " " . .	1610	8.21	1.97	
7	" " " . .	1548	8.88	3.44	
12	" " " . .	1593	10.15	4.65	
8	" " " . .	1536	11.75	2.20	
13	" " " . .	1576	12.05	5.14	
9	" " " . .	1528	12.66	4.09	
14	" " " . .	1568	13.99	4.68	
15	" " " . .	1517	15.47	3.71	
10	7″ double belt, . .	1617	6.11	2.70	Horizontal belt. This belt was rather slack.
11	" " " . .	1631	8.21	4.29	
12	" " " . .	1617	10.15	5.70	
13	" " " . .	1600	12.05	6.90	
14	" " " . .	1591	13.99	6.35	
15	" " " . .	1539	15.47	7.94	

It will be seen that when the belts were ordinarily tight the slip would average about three feet per minute.

I will next proceed to give a summary of the tests for determining the co-efficient of friction during 1884–85, a part of which were done as regular laboratory exercises, and a part by Mr. A. L. Merrill for his thesis : —

HAIR SIDE NEXT PULLEY.

Test No.	Speed of Slip, in feet, per Minute.	Ratio of Tensions.	Co-efficient of Friction.
1	2.09	2.22	0.255
2	2.09	2.23	0.255
3	2.09	2.22	0.255
4	2.09	2.23	0.255
5	2.09	2.23	0.255
6	2.09	2.08	0.235
7	2.09	2.02	0.225
8	2.09	2.03	0.225
9	2.09	2.02	0.225
10	2.09	2.03	0.225
Average, .	2.09	2.12	0.240

HAIR SIDE NEXT PULLEY.

Test No.	Speed of Slip, in Feet, per Minute.	Ratio of Tensions.	Co-efficient of Friction.
21	6.84	2.39	0.275
22	6.84	2.41	0.280
23	6.84	2.48	0.290
24	6.84	2.58	0.300
25	6.84	2.67	0.313
26	7.00	2.88	0.337
27	7.00	2.96	0.345
28	7.00	2.83	0.330
29	7.00	2.90	0.339
30	7.00	2.90	0.339
Average, .	6.92	2.64	0.310

HAIR SIDE NEXT PULLEY.

11	2.83	2.34	0.270
12	2.83	2.38	0.275
13	2.83	2.38	0.275
14	2.83	2.39	0.275
15	2.83	2.41	0.280
16	2.38	2.49	0.290
17	2.38	2.49	0.290
18	2.38	2.50	0.291
19	2.38	2.49	0.290
20	2.38	2.51	0.294
Average, .	2.605	2.438	0.283

FLESH SIDE NEXT PULLEY.

31	2.09	1.93	0.210
32	2.09	1.93	0.210
33	2.09	1.92	0.210
34	2.09	1.92	0.210
35	2.09	1.91	0.210
Average, .	2.09	1.92	0.210
36	3.38	2.27	0.260
37	3.38	2.18	0.250
38	3.38	2.16	0.246
39	3.38	2.17	0.248
40	3.38	2.16	0.246
Average, .	3.38	2.19	0.250
41	7.00	3.20	0.370
42	7.00	3.17	0.367
43	7.00	3.11	0.361
44	7.00	3.06	0.357
45	7.00	3.05	0.355
Average, .	7.00	3.12	0.363

No. of Experiment.	Kind of Belt.	Side next Pulley.	Nature of Pulley.	Co-efficient of Friction.	Speed of Slip, in Feet, per Minute.
18	Oak-tanned, ...	Hair, . . .	Cast-iron,	0.776	238.0
19	"	Flesh, . . .	"	0.45	238.0
20	"	Hair, . . .	"	0.82	210.0
21	"	Flesh, . . .	"	0.51	210.0
22	"	" . . .	"	0.37	15.4
23	"	Hair, . . .	"	0.30	15.4
24	"	" . . .	"	0.33	15.0
25	"	" . . .	"	0.33	15.0
26	"	Flesh, . . .	"	0.36	15.0
27	"	Hair, . . .	"	0.34	16.9
28	"	Flesh, . . .	"	0.42	16.9
29	Raw hide, ...	Hair, . . .	"	0.36	14.9
30	" "	Flesh, . . .	"	0.38	14.9
31	" "	Hair, . . .	"	0.33	15.1
32	" "	Flesh, . . .	"	0.45	15.1
33	" "	Hair, . . .	"	0.38	13.9
34	" "	Flesh, . . .	"	0.45	13.9
35	" "	Hair, . . .	"	0.42	14.9
36	" "	Flesh, . . .	"	0.52	14.9
37	" "	" . . .	"	0.74	12.8
38	" "	" . . .	"	0.67	12.8
39	Oak-tanned, ...	Hair, . . .	"	0.43	12.7
40	"	" . . .	"	0.37	12.7
41	"	" . . .	"	0.32	12.7
42	"	Flesh, . . .	"	0.37	12.4
43	"	" . . .	"	0.31	12.4
44	"	" . . .	"	0.32	12.4
45	Raw hide, ...	" . . .	"	0.60	12.5
46	" "	" . . .	"	0.58	12.5
47	" "	" . . .	"	0.57	12.5

I will give next the values of $\frac{T_1}{T_2}$ correspondiug to each of these co-efficients of friction, with 180° arc of contact: —

For $f = .17$ $\qquad \frac{T_1}{T_2} = 1.708$

" $= .27$ $\qquad \frac{T_1}{T_2} = 2.335$

" $= .42$ $\qquad \frac{T_1}{T_2} = 3.776$

It may be well that I should, before going farther, explain how to use the co-efficient of friction, or the ratio of the tensions in determining the proper width of belt to transmit a given power at a given speed. When we know the foot pounds of work to be done per minute, and the feet per minute traveled by the belt, we obtain by division the effective pull, or the difference of the tensions ($T_1 - T_2$). Thus if we are to transmit 30 H. P. at a belt travel of 1500 feet per minute, we should have —

$$T_1 - T_2 = \frac{30\ (33{,}000)}{1500} = 660 \text{ lbs.} \qquad (1)$$

Now, as soon as we know the ratio $\frac{T_1}{T_2}$ we can at once obtain the value of T_1, and as soon as T_1 is known, we determine the width of belt by dividing T_1 by the greatest admissible stress per inch of width. Thus we should obtain in this case —

For $f = 0.17$	$T_1 = 1592$ lbs.
" $= 0.27$	$T_1 = 1154$ "
" $= 0.42$	$T_1 = 898$ "

Now, knowing the tension required on the tight side, we determine the width of belt required as soon as we know the greatest allowable tension per inch of width. This is given by Briggs and Towne as $66\frac{2}{3}$ lbs. $= \frac{1}{3}$ (200) lbs., 200 lbs. being a fair average value of the breaking strength per inch of width of a laced belt, breaking through the lace-holes.

If we assume this value for the greatest allowable tension per inch of width, we obtain —

For $f = 0.17$,	width required $= 24.''$ inches.
" $= 0.27$,	" " $= 17.''3$ "
" $= 0.42$,	" " $= 13.''4$ "

The following table will now be intelligible, exhibiting as it does the results thus far obtained under a variety of aspects: —

	Co-efficient of Friction.	T_1 required to transmit 1 H.P. at 1000 Ft. per Minute, in Lbs.	T_2 corresponding, in Lbs.	$T_1 + T_2$ corresponding, in Lbs.	T_1 required to transmit 1 H.P. at 1500 Ft. per Minute, in Lbs.	T_2 corresponding, in Lbs.	$T_1 + T_2$ corresponding, in Lbs.
Morin, ...	0.28	55.2	22.2	77.4	36.8	14.8	51.6
Towne (experiments)	0.58	39.3	6.3	45.6	26.2	4.2	30.4
Towne (given to be used), ...	0.42	45.0	12.0	57.0	30.0	8.0	38.0
Sawyer, ...	0.12 to 0.17	105.0 to 79.6	72.1 to 46.6	177.0 to 126.2	70.0 to 53.0	48.0 to 31.0	118.0 to 84.0
M. E. Lab., with slip of 3 feet per minute, ...	0.27	57.8	24.8	82.6	38.5	16.5	55.0

For different arcs of contact from 180° the ratio of tensions would be different, being given by the formula $\frac{T_1}{T_2} = e^{f\theta}.$

It would seem reasonable that, with a belt travel of about 1500 feet per minute, which is about the speed of the belts used in making the slip tests, the speed of slip should not be more than about three or four feet per minute; and this would necessitate a co-efficient of friction of about 0.27, which means that the belt should have a strain of 55 pounds per horse-power transmitted. This is the value of the co-efficient of friction deduced as an average by Mr. Merrill in the tests that he made for his thesis. It is also evident that, if we use a higher co-efficient, as 0.42, we must, in order to realize it, have a strain upon the belt of only 38 pounds per horse-power transmitted; but then we should have a speed of slip much larger than would be suitable to use in practice; and that, if we determine the width of the belt on the basis of 38 pounds, and then strain it more, we are no longer keeping within the limits of safety intended.

While the work described above would seem to throw a great deal of light upon the problem of belting, there are two objections that might be theoretically raised to this form of experiment, which objections can only be refuted by another form of experiment. These objections are as follows: —

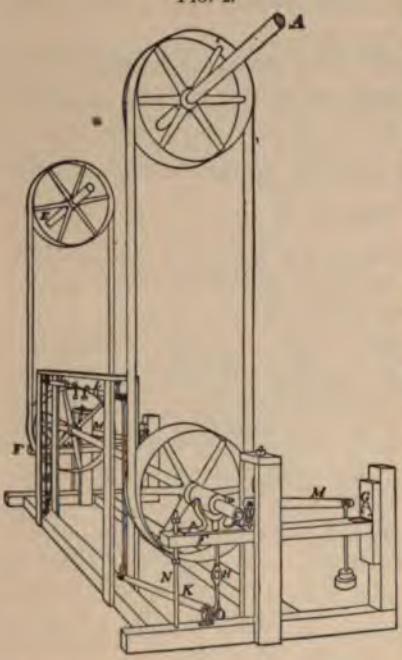
1°. Is the ratio of the tensions the same when the belt is driving as when either the belt slides over the pulley, or the pulley under the belt?

2°. Is the ordinary friction theory correct for a driving belt?

In regard to this I will say that we have undertaken another kind of experiment in which we do not even assume the friction theory of belting, and which I will describe next, and that the results obtained thus far bear out quite well the previous results.

The form of experiment, and the machine used, will be now described. (See Fig. 2.)

FIG. 2.



The power is transmitted from the shaft A to the shaft C, and thence to the shaft E, by means of the two vertical belts shown in the figure (the four pulleys on which these run being of equal size); the shafts A and E being in one line, but not being one and the same shaft. From the shaft E the power is transmitted by means of a belt to a nicely made Prony brake, where it is weighed, and by adding to the power shown by the brake the power required to drive the shaft E itself (determined by dynamometer), we have the power transmitted through each of our vertical belts, and by means of a revolution-counter attached to the shafts C and E, we obtain their numbers of revolutions, and hence the speed of the vertical belts, and hence by division the value of $T_1 - T_2$ for each one.

The boxes in which the shaft C runs are fixed to the planks F F, and these are attached by the hinges G G to two fixed uprights, the rod N being smaller than the hole in F, through which it passes,

and being merely used as a safety-stop. The planks *F F* are, therefore, free to turn up and down about the hinges *G G*. The levers *M M* are merely counterweighting levers.

The desired tension is put upon the vertical belts after they are in position by means of the turn-buckles in the links *H H*, which are attached to the levers *K K*, and thence to the scale-beams *L L*. The weights shown on the scale-beams are, therefore, the sums of the tensions, or the values of $T_1 + T_2$.

Besides this, a revolution-counter is attached to the shaft *A*, and another to the shaft *E*, and hence we readily obtain the slip of each belt.

Prof. Peabody, Prof. Schwamb, and myself have all had a hand in getting up this apparatus for the laboratory.

I have already explained how, when the power transmitted and the speed are known, we can obtain $T_1 - T_2$, and have explained that, when using the friction theory, we use the ratio $\frac{T_1}{T_2}$ to determine T_1 and T_2, and hence the width of belt required.

In this new form of experiment we determine instead $T_1 + T_2$ by actually weighing it on a scale; hence we obtain the exact values of T_1 and T_2 without any assumptions whatever, and we are, therefore, enabled to answer the following questions: —

1°. In order to transmit a given power at a given speed of belt, what is the least value of $T_1 + T_2$ with which we can succeed to drive at all, without having the belt slip off? What is the speed of slip we obtain under these conditions, and what the values of T_1 and T_2?

2°. If a given power is to be transmitted with a given speed, and the speed of slip is not to exceed a given quantity, what is the value of $T_1 + T_2$ required for the purpose? and what are T_1 and T_2?

Having answered these questions, the question of width of belt is to be determined by so fixing it that it shall be able to bear the required value of T_1 without injury, and without losing its tightness. The following table gives a summary of the results thus far obtained:

No. of Test.	Horse-Power.	Speed of East Belt, feet per min.	Speed of West Belt, feet per min.	Slip of East Belt, feet per min.	Slip of West Belt, feet per min.	$T_1 + T_2$	T_1 of East Belt.	T_1 of West Belt.	$\frac{T_1}{T_2}$ of East Belt.	$\frac{T_1}{T_2}$ of West Belt.	f for East Belt.	f for West Belt.	$T_1 + T_2$ per H.-P.
46	16.88	1497	1512	14.92	27.48	475	423.6	421.8	8.241	7.928	0 67	0.66	28.1
50	17.00	1510	1524	14.14	20.42	500	435.8	434.1	6.788	6.587	0.61	0.60	29.4
1	4.86	1440	1489	48.60	40.80	150	130.7	128.9	6.720	6.109	0.61	0.58	31.0
22	4.86	1440	1489	48.60	40.80	150	130.7	128.9	4.434	4.177	0.48	0.45	31.0
26	8.49	1522	1528	6.83	25 68	300	242 0	241.6	4.172	4.137	0.45	0.45	35.3
17	9.23	1455	1488	10.47	22.53	325	267.3	264.9	4.633	4.408	0.49	0.47	35.2
53	14.25	1420	1464	44.45	60.79	525	428.1	423.1	4.418	4.152	0.47	0.45	36.8
18	9.42	1489	1491	3.14	25.68	350	279.4	279.2	3.958	3.943	0.44	0.44	37.1
54	14.72	1468	1491	22.38	35.58	550	440.4	437.9	4.018	3.906	0.44	0.43	37.4
14	10.44	1528	1536	7 85	14.69	400	312.7	312.1	3.582	3.551	0.41	0.40	38.3
55	14.79	1475	1496	20 97	30.39	575	452.9	450.6	3.709	3.622	0.42	0.41	38.8
52	12.83	1470	1462	7.85	16 81	500	394.8	394.1	3.753	3.721	0.42	0.42	39.0
29	8.31	1488	1492	5.50	30.63	325	254.7	254.4	3.631	3.603	0.41	0.41	39.1
19	9.55	1511	1519	8.32	14.69	375	291.6	291.2	3.496	3.475	0.40	0 40	39.2
51	10.51	1535	1543	7.85	14.14	425	325.5	324.9	3.271	3.245	0.38	0.38	40.4
47	12.81	1459	1468	8.40	14.61	525	407.4	406.5	3.464	3.430	0.40	0.39	41.0
24	8.50	1526	1530	4.71	18.38	350	266.8	266.7	3.212	3.202	0.37	0.37	41.2
32	10.87	1460	1467	6.83	15.71	450	347.9	347.3	3.403	3.382	0.39	0.39	41.4
48	12.77	1454	1462	7.89	14.14	550	419.9	419.2	3.227	3.205	0.37	0.37	43.0
15	10.44	1527	1534	6.75	14.69	450	337.8	337.3	3.010	2.993	0.35	0.35	43.1
6	4.58	1504	1519	14.90	16.50	200	150.3	149.8	3.024	2.958	0.35	0.34	43.6
31	10.94	1462	1467	5.26	14.14	475	361.0	360.6	3.167	3.152	0.37	0.37	43.4
28	8.45	1516	1520	3.93	18.85	375	279.5	279 3	2.927	2.919	0.34	0.34	44.4
44	12.95	1484	1477	7.30	15.16	575	432.2	431.5	3.027	3.007	0.35	0.35	44.4
30	11.01	1468	1474	6.28	13.12	500	373.7	373.2	2.959	2.943	0.34	0.34	45.4
3	4.95	1488	1499	11.80	14.10	225	167.4	167 0	2.906	2.879	0.34	0.33	45.5
23	10.35	1523	1529	6.28	13.35	475	349.7	349.2	2.791	2.776	0.33	0.33	45.9
33	11.27	1504	1510	6.28	14.14	525	386.1	385.6	2.780	2.766	0.33	0.32	46.5
25	8.53	1532	1536	4.71	13.12	400	291.9	291.6	2.700	2.690	0.32	0.32	46.7
43	12.70	1459	1452	6.28	14.69	600	444.3	443.7	2.854	2.839	0.33	0.33	47.2
16	10.40	1526	1533	7.30	14.14	500	362.5	361.9	2.636	2.621	0.31	0.31	48.1
35	11.33	1517	1523	6.24	13 35	550	398.3	397.8	2.626	2.614	0.31	0.31	48.5
41	12.85	1458	1465	7.30	14.14	625	457.9	457.2	2.742	2.725	0.32	0.32	48.6
9	5.06	1550	1551	1.30	12.30	250	178.9	178.9	2.516	2.516	0.29	0.29	49.4
22	10.42	1532	1537	5.50	12.57	525	374.7	374.3	2.493	2.484	0.29	0.29	50.3
21	10.48	1537	1543	5.50	11.78	525	400.0	399.6	2.286	2 278	0.26	0.26	50.1
27	8.45	1515	1517	2.36	14.14	425	304.5	304.4	2.527	2.524	0.30	0.30	50.3
42	12.77	1456	1462	6.83	14.69	650	469.8	469.1	2.607	2.593	0.30	0.30	50.9
34	11.30	1511	1517	5.50	13.35	575	410.9	410.5	2.504	2.495	0 29	0.29	50.9
4	4.78	1522	1528	4.50	3.10	250	176.8	176.6	2.415	2.406	0.28	0.28	52.3
46	12.78	1462	1460	1.81	14.69	675	481.9	481.7	2.496	2.492	0.29	0.29	52.8
45	12.96	1477	1484	7.85	13.59	700	494.8	494.0	2.411	2.398	0.28	0.28	54.0
38	10.97	1463	1471	7.30	13.67	600	423.7	423.1	2.403	2.391	0.28	0.28	54.7
13	5.03	1540	1544	3.69	8.87	275	191.8	191.7	2.294	2.290	0.26	0.26	54.6
10	5.03	1540	1544	0.40	8.90	275	191.4	191.3	2.289	2.285	0.26	0.26	54.6
12	5.00	1521	1526	4.71	12.57	275	191.8	191.6	2.305	2.297	0.27	0.26	55.0
7	4.95	1521	1526	4.70	12.60	275	191.2	191.0	2.278	2.274	0.26	0.26	55.5
37	11.02	1469	1474	5.26	13.59	625	436.3	435.9	2.312	2.305	0.27	0·27	56.7
5	4.79	1529	1536	7.70	5.60	275	189.5	189.0	2.213	2.197	0.26	0.25	57.4
36	11.13	1489	1494	5.26	13.59	650	448.4	447.9	2.224	2.216	0.25	0.25	58.4
11	5.06	1550	1552	2.59	9.50	300	203.9	203 8	2.121	2.121	0.24	0.24	59.2
8	5.02	1527	1531	3.90	11.80	300	204.2	204.1	2.132	2.128	0.24	0.24	59.7
39	5.74	1583	1583	0.79	7.07	575	347.4	347.3	7.526	1.525	0.13	0.13	100.0
40	5.74	1583	1582	0.79	8.64	600	359.9	359.9	1.499	1.499	0.13	0.13	104.5

While there are more or less irregularities in these tests, for some of which the reason is not yet clear, nevertheless a perusal of the table will, I think, make it plain that, in order to obtain fair running, we need to use a value of $T_1 + T_2$ at least as great as 55 lbs. per horse-power. and this corresponds to a co-efficient of friction of about 0.27. It is also plain, it seems to me, that a co-efficient of friction, 0.42, corresponding to $T_1 + T_2 = 38$, is entirely wrong, and is never realized in practice with fair running.

Now, this work with the belting gives us the amount that it is necessary to strain a belt in order to carry a certain power at a certain speed, with no more than a certain amount of slip; and there remain two things to be attended to: 1°. Our belts ought to be put on in practice with a known tension. 2°. The criterion that determines the proper width should be the least of the two following quantities, viz., the breaking strength divided by a suitable factor of safety, or the greatest tension which the belt can hold for a reasonable length of time.

It has thus far been the first that has been accepted as the proper criterion, and it is possible that this may be a reasonable thing to do with laced belts, but with a glued belt, such as any of our double belts, it is the latter that should be used. In this regard there never have been any figures whatever determined, and we propose to make experiments upon it, running the belting machine for a week at a time. and noting how the load drops off.

Next, in regard to anomalies: it will be noticed that the west belt slips almost always more than the east. The reason of this has not yet been ascertained; but the probability is that the results with the east belt are the most reliable.

Another question of interest is that the value $T_1 + T_2$ which is measured while the belt is running decreases as soon as the load is let off, if the load is at all considerable.

MEETING 343.

The Cowles' Electric Furnace, and the Production of Aluminum and its Alloys.

BY MR. A. H. COWLES.

The 343rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, February 11th, at 8 P. M., Mr. George W. Blodgett in the chair.

After the reading of the minutes of the last meeting, and the election of new members, the chairman introduced Mr. A. H. Cowles, of Cleveland, O., who read a paper on "The Cowles' Electric Furnace, and the Production of Aluminum and its Alloys."

Mr. COWLES said: I will this evening describe our Electric Furnace, and recently-discovered process for the cheaper production of that wonderful metal aluminum, as well as other rare metals and new alloys.

A quarter of a century ago Prof. Faraday, in a lecture on platinum, described what was probably the first electric furnace ever designed. This furnace was one in which Deville, who, under the auspices of Napoleon III., made such great advances in the production of aluminum, proposed to purify platinum. He accomplished this by heating the platinum to such a temperature that the baser metals were volatilized, leaving the platinum pure. I will quote the following paragraph from this lecture: —

"I have here an apparatus by which this thing can be shown. Here is a piece of platinum, which is put into a crucible of carbon, made at the end of one pole of a *battery*, and you will see the brilliant light that will be produced. There is our furnace, and the platinum is rapidly getting heated; and now you perceive that it is melted, and throwing off little particles." And now that scientist, evidently looking into the future, exclaimed: "What a magnificent philosophical instrument this is!"

Since then nothing more was accomplished in the application of electricity to heating furnaces till 1880. In June of that year, Sir William Siemens described before the Society of Telegraph Engin-

eers a furnace designed to melt considerable quantities of such excessively refractory metals as platinum, iridium, and steel. It differed from the furnace used by Deville in having a carbon rod for one electrode, and the metal contained in a graphite crucible as the other electrode. The crucible was surrounded on the *outside* by fine charcoal. Inside an arc was formed, which was adjusted by proper mechanism. He explained that he was led to undertake experiments of this nature by the consideration that a good steam-engine converts fifteen per cent of the energy residing in coal into mechanical effect; while a good dynamo electric-machine is capable of converting eighty per cent of that mechanical energy into electrical energy. If the latter could be expended without loss within an electric furnace, it would doubtless far exceed in economy that of the air furnaces still largely used in Sheffield. Other important work, and his death two years later, probably prevented the further development of this furnace.

A year later Faure took out patents for an electric furnace designed for the reduction of sodium and potassium. At this time the science of chemistry had quite reached the point where it was ready to say that the oxides of such metals as aluminum, calcium, magnesium, and metalloids, as boron and silicon, were not susceptible of reduction with carbon as the reducing agent. It may be from this cause that he did not cover a broader field, or from some imperfection in his furnace, that he did not put into execution the splendid idea of manufacturing by a cheaper process sodium and potassium.

I will now continue with a description of the furnace. It is simple in construction, being what might be called a rectangular box, one foot wide, five feet long inside measurement, and fifteen inches deep, and made of fire-brick. From the opposite ends, through pipes, the two electrodes and holders pass. The electrodes are immense electric-light carbons, three inches in diameter, and thirty inches long. The ends are placed within a few inches of each other, in the center of the furnace. The pipes contain packing boxes which prevent the air from entering into the interior. The furnace now operated at the main works of the Brush Electric Company, in Cleveland, is connected with the largest dynamo ever made by that company. It produces about 70,000 watts of current, or about ninety electrical horse-power, as its average work. In this circuit, between the furnace

and dynamo, is placed the resistance box, and an ammeter. The resistance box is so contructed that a variable resistance may be thrown into the circuit, if such be desired in controlling the current. The ammeter was designed by Mr. Brush, and is so constructed as to take from fifty to two thousand amperes of current around its helices, and register the same upon its dial.

These connections having been made, the furnace is now ready to receive the charge. The walls of the furnace must first be protected, otherwise the intense heat generated within the interior would cause the fire-brick to melt and flow like water. What is the best substance to line the walls with? Finely-powdered charcoal is comparatively a poor conductor of electricity. It is considered infusible, and is the best non-conductor of heat of all known solids. From these properties it would seem to be the best material to use as a lining for the furnace. So long as the air is excluded it is impossible for it to burn. But we find, after using pure charcoal for a few times, that it becomes valueless. It retains its woody structure, as is shown in the larger pieces, but it has changed to graphite, becoming a good conductor of electricity, and thereby it tends to diffuse our current through the lining, heating it and the walls. We therefore wash the fine charcoal in a solution of lime-water. After drying, each particle is insulated by a fine coating of lime. The bottom of the furnace is now lined to a depth of two or three inches with this prepared charcoal. A sheet-iron gauge is placed along the sides of the electrodes, leaving about two inches between it and the side walls. In this space more fine charcoal is placed. The charge, consisting of about twenty-five pounds of the oxide of aluminum, in its native form as the mineral corundum, twelve pounds of charcoal and carbon, and fifty pounds of granulated copper, is now placed within the gauge, and spread around the electrodes to within a foot of each end of the furnace.

After this is done, a bed of charcoal, the granules of which vary in size from that of a chestnut to that of a hickory nut, is spread over the charge, and the gauge withdrawn. This coarse bed of charcoal above the charge allows free escape for the carbonic oxide gas generated during the reduction. The charge being in place, an iron top, lined with fire-brick, is placed over the whole furnace, and the crevice luted to prevent the entrance of air. The brick of the walls insulate this cover from the current.

Now that the furnace is charged, and the cover luted down, we are ready to start, and observe what takes place. The ends of the electrodes were in the beginning placed close together, and from this cause the internal resistance of the furnace may be too low for the dynamo, and cause a short-circuit. We, therefore, throw sufficient resistance within the circuit, by means of the resistance box, to make it safe to start the dynamo. This being done, an attendant gradually takes the resistance of the box out of the circuit, and, by watching the ammeter, and now and then moving one of the electrodes out a trifle, he is enabled to prevent undue short-circuiting in the beginning of the operation. In about ten minutes the copper between the electrodes has become melted, and the latter are moved far enough apart so that the current becomes steady. The current is now allowed to increase till we are drawing from the dynamo about thirteen hundred amperes, driven by fifty volts. Carbonic-oxide gas has already commenced escaping through the two orifices in the top, and there it burns to carbonic-acid gas, forming two white plumes of flame. By slight movements outward of the electrodes during the coming five hours, the internal resistance of the furnace is kept constant, and at the same time all the different parts of the charge are brought in turn into the zone of reduction. At the close of the run, we shut the furnace down by placing a resistance in the box, and then switching the current into another furnace, which has been charged in a like manner.

During five hours there has been, we might say, pumped into the furnace ninety electrical horse-power. By Jouls's equivalent, when this power is changed to heat, it equals one million one hundred and fifty-four thousand Fahrenheit heat units, or sufficient heat, if it were devoted to heating the fifty pounds of copper alone contained within the furnace, to raise it to a temperature of two hundred and forty-two thousand degrees, were such a thing possible. During the beginning of the operation the copper first melted in the center of the furnace. There was no escape for the heat that was continually generated. The temperature increased till the refractory corundum melted, and, being surrounded on all sides by carbon, gave up its oxygen, and thereby complies with Berthollet's law. The heat of the union of the oxygen liberated from the aluminum uniting with the sesquioxide carbon has certainly aided in the economy of the process.

The copper has had nothing to do with the reaction, as it will take place in its absence.

Whether the reduction is due to the intense heat, to electrolytic action, or both, is difficult to say. If it be electrolysis, it is my impression that we have here a case where electrolysis can be accomplished with an alternating current, although it has not been tried as yet. Were the copper absent, the freed aluminum would now absorb carbon, and become a yellow crystalline carburette of aluminum; but, instead of that, the copper has become a boiling, seething mass, and the bubbling of its vapors may be distinctly heard. The vapors probably rise an inch or two, condense, and fall back, carrying with them the freed aluminum. This continues until the current is taken off from the furnace, when we have the copper charged with from fifteen to thirty per cent of its weight of aluminum. After cooling the furnace this rich alloy of aluminum and copper is removed.

Here we note again another valuable property of the fine charcoal. The capillary action between it and molten metal is such that the metal does not spread and run through its interstices, but remains a liquid mass surrounded below and on the sides by fine charcoal. The alloy presents a white appearance, and is of a brittle nature. This metal is now melted in an ordinary crucible furnace, poured into large ingots, and the amount of aluminum it contains is determined by analysis, after which it is again melted, and the requisite copper added to make the valuable aluminum bronzes, of which we will speak later.

Two runs, as described, will produce, in ten hours' average work, about one hundred pounds of this white metal, containing about fifteen pounds of aluminum. From this data it has been carefully estimated that aluminum itself, in its alloys, can be produced at about forty cents a pound in the works now being erected by the Cowles' Electric Smelting and Aluminum Company, at Lockport, New York, and the production of it pure, although the problem lacks some links in its economic solution, will surely not double that cost. This estimate is based upon the present size and form of furnace. As to its future possibilities, it is difficult for one to form definite opinions. To my mind, it is now as crude as the ancient Spanish adobe furnace for the production of lead and silver, or the old Catalan forge which was used in the early production of iron. With electricity, we have at

hand a beautiful means of future automatic regulation of the electrodes, of the feeding of the charge, of the working of the dynamo, and of the driving of machinery, so that all parts may be made to work in perfect harmony. Within the coming year the Cowles' Electric Smelting and Aluminum Company will have facilities to concentrate within one furnace the energy of twelve hundred horse-power, or nearly that of the great Corliss engine, which furnished the power for Machinery Hall at the Centennial ten years ago. With a larger furnace there is no reason why it should not be made to run continuously like the ordinary blast furnace.

The temperature attainable within the furnace is only limited by the fusion point of carbon; as yet we have not reached this limit. The charcoal is easily changed to graphite, but so far it has always retained its woody structure. A run, carefully made with this fusion in view, would be intensely interesting, as it would probably solve the question as to whether the diamond is a product of fusion, or a product of crystallization from a solution. The fusion of the corundum frequently gives us minute crystals of the ruby and sapphire.

Pure white sand is not only made to melt, but is easily reduced to silicon. Here we have a mass of minute crystals of silicon, that came from a fire brick being placed within the furnace, and too near the center of heat. The other elements that were present seem to have volatilized, leaving nothing but the silicon behind.

Boron, sodium, potassium, calcium, magnesium, chromium, and titanium have all been reduced in the furnace. It is safe to say that no metallic oxide can resist the intense reducing forces that are here brought to bear upon it. To go further into the great chemical possibilities of electric smelting would take too much time.

In the operation of the furnace, copper was used to gather the aluminum together, and to prevent its formation into carburette of aluminum, or into the amorphus powder. The copper acts somewhat as a condenser to the metallic fumes of aluminum liberated. In place of the copper, any non-volatile metal may be used as a condenser, to unite with any metal we may desire to reduce; provided. of course, the two metals are of such a nature that they will alloy with each other at this high temperature. In this way aluminum may be produced and obtained, alloyed with iron, nickel, silver, tin, or cobalt. We have made alloys containing fifty per cent of aluminum, and fifty

per cent of iron; twenty-five per cent of aluminum, and seventy-five per cent of nickel; thirty per cent of aluminum, and seventy per cent of copper. Silicon or boron, or other rare metals, may be combined in the same manner, or tertiary alloys may be produced,—as, for instance, when fire clay is reduced in the presence of copper, we obtain an alloy of silicon, aluminum, and copper. This is a white, brittle alloy when more than ten per cent of aluminum and silicon is present in the copper. With from two to six per cent of aluminum and silicon in equal proportions, the alloy is stronger than gun metal, has great toughness, does not oxidize when heated in the air, and has fine variations of yellow gold color.

It is difficult to say which of this great number of possible combinations of metals will form valuable alloys, and find their way into the arts. It is very possible that some of them may prove as much finer than aluminum bronze as that bronze is finer than gun metal. Who can tell? History may repeat itself, and the world may return to a bronze age. In the case of these rare metals, which are, in fact, the common metals of the earth's crust, what part will they play in the future history of mankind? It is a fact that there is no element which has been procured cheaply in the past but that has become an important factor in the work of civilization.

In aluminum and some of its alloys, and in silicon alloyed with copper and tin, and known as silicon bronze, we have metals that heretofore have been procured by old and expensive processes, and whose remarkable physical properties have been quite thoroughly studied.

Here is a small ingot of aluminum which was produced from its oxide, with carbon as the reducing agent in the electric furnace. [Sample shown.] It is not quite pure, its specific gravity being two and eight-tenths. When pure a casting should have a specific gravity of two and five-tenths. It is as strong as iron or copper, if equal cross-sections be compared, or as strong as steel if equal weights be taken in comparison. Under the hammer it works like the best Norway iron. In color it approaches silver, and has been called the silver made from clay. Neither the oxygen of the air, or sulphurous-acid gas will attack it at ordinary temperatures. We have found that ten per cent of copper added to it renders it hard and rigid, not materially changing its color or luster, and in the testing machine it showed

a strength greater than cast iron by one half. Pure, it can be rolled into sheets or drawn into the finest wire. Its electrical conductivity is sixty-four, copper being one hundred. Taking its specific gravity into consideration, we find it is two and one-fifth times as efficient as copper, and about twenty times as efficient as iron as an electrical conductor. In other words, aluminum wire at one dollar and twenty cents a pound would be as cheap as iron wire at six cents for electrical purposes, and have the advantage of using but one-twentieth the weight. In alloying with other metals it seems to impart in almost every case new and valuable properties to the resultant alloy. Here is a sample of the finest grade of aluminum bronze. [Sample shown.] It contains about eight and one-half per cent of aluminum and one per cent of silicon. Tests have shown that silicon increases its strength, and does not interfere with its fine color or luster. Cast samples have shown as high as one hundred and seventeen thousand pounds tensile strength to the square inch. In making this bronze, the white metal, rich in aluminum, is first melted, and then the requisite copper added to it till a sample can be taken from the crucible which shall show a test of ninety thousand pounds or over. Unlike ordinary brass or bronze, it will stand remelting or long-continued heat without marked deterioration. This was proved by melting one hundred pounds in a crucible. After it was melted a test was made which showed ninety-five thousand pounds tensile strength, and six per cent elongation. The metal was now kept at an intense heat for four and one-half hours. At the end of that time it was again tested, and showed eighty-three thousand pounds tensile strength, and eleven per cent elongation. No appreciable loss could be detected in the weight. In hardness it does not quite equal untempered tool steel, yet it is so hard that a polished surface is not easily scratched. As an anti-frictional metal it is said to be unsurpassed. Its fine color and permanent luster have enabled it to find a ready use at its past high price for ornamental articles, and its great strength has led to its use in many places where strength and beauty were desired. It has been highly recommended for heavy artillery. Its high price in the past seems to have been the only cause that has precluded its use in guns, propeller wheels, and a thousand and one places where great strength is desired without the work of forging steel. At a red heat aluminum bronze is malleable, and, unlike copper or ordinary bronzes,

it may be heated, and as many as a dozen sheets of metal may be rolled in a pack at the same time, thus enabling it to be rolled very cheaply.

If the percentage of aluminum in the alloy be reduced to seven and one-fourth, and of silicon to three-fourths, we obtain a metal with a tensile strength ranging from sixty-six thousand to seventy-seven thousand pounds to the square inch, and from twenty-five to forty-four per cent elongation of its original length. In other words, it has more than three times the strength of copper, and surpasses it in ductility.

The five per cent aluminum bronze has a fine yellow gold color, does not oxidize, is about as strong as gun metal, but more ductile.

Two and one-half per cent of aluminum in copper gives it a fine red gold color, and prevents oxidizing in the air even at a red heat.

Some of the brasses are greatly increased in strength, permanency of luster, and ductility by the addition of from one to three per cent of aluminum. This is well illustrated by the following tests made from test bars that were cast attached to a hundred-pound casting. The composition of the metal before melting was two parts in weight of five per cent aluminum bronze and one part of zinc. One of the bars registered 91,196 pounds tensile strength, and 4.6 per cent elongation, and the other 94,416 pounds, and seven per cent elongation. This surpasses Prof. Thurston's maximum tin, copper, and zinc alloy by twenty thousand pounds in tensile strength, and by a considerable percentage in elongation. Yet there is a large field for investigation in the possible alloys of zinc, copper, and aluminum.

Knife blades, cast in sand, from German silver containing three per cent of aluminum, have been made and finished. The aluminum changes the German silver to a color lighter than steel, but not so white as silver, and renders it non-tarnishable, hard, elastic, and strong enough to whittle hickory.

At the close of the lecture, a large variety of articles, made of aluminum alloys, were exhibited.

MEETING 344.

The Transmission of Steam.

BY MR. CHARLES E. EMERY.

The 344th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Feb. 25th, at 8 P. M., Prof. Gaetano Lanza in the chair.

After the reading of the minutes of the last meeting, the chairman introduced Mr. Charles E. Emery, of New York, who read a paper on "The Transmission of Steam."

The lecturer stated that the nature of the difficulties encountered in transmitting steam for a considerable distance are not generally understood. Condensation necessarily takes place, as is expected, but non-conductors may be applied to reduce this loss to so small a proportion of the carrying capacity of the pipes that it will not form a serious disadvantage in a mere commercial sense. The problem may be called difficult on account of the number of principles involved, and the mass of engineering and mechanical details required to apply the principles correctly and successfully. Condensation is but one of the many conditions to be provided for, and, in some respects, an embarrassing one, but it can be satisfactorily dealt with much more readily than several others.

The expression, "A District Steam System," is now accepted as referring to a plant in which steam, generated in a central station, is distributed through under-ground pipes laid in the public streets, so that the steam may be taken at will by consumers "on tap," so to speak, the same as gas and water. Such a plant is, in some respects, similar to, and at first sight would appear to be only an enlargement of, the method of distributing steam from a central point to the buildings of a large factory or public institution. In fact, however, the conditions encountered in putting pipes in streets already full of under-ground obstructions, such as other pipes, vaults, sewers, etc., in such a manner that consumers can be accommodated when and where desired, involve many more difficulties, and require many modifications in detail, compared with a system where all the property is under one control,

where space under ground is rarely obstructed or valuable, and where the whole plant, with all its ramifications, may be laid out before the work is commenced.

The lecturer then referred to the work of the New York Steam Company, stating that the standard pressure in the mains had been fixed at eighty pounds, and that the pipes were proportioned for a loss of pressure of ten pounds in half a mile. The loss of pressure at present is only two pounds in that distance, as the plant is not as yet worked at its full capacity.

Dry or saturated steam is well adapted for successful transmission to a distance, for the simple reason that the temperature always corresponds to the pressure. It follows, therefore, that steam of a given pressure is as valuable at the distance of a mile or more from the boiler in which it is generated as it is at the boiler itself; also, that steam mixed with water has, when the water is removed, all the properties, and is equally valuable, as any other steam of the same pressure. In short, steam does not *deteriorate* the least in transmission so long as it is steam; that is, has been freed of the water of condensation incident to its transmission. The problem of separating steam from water is well understood. Evidently, if a mixture of steam and water be passed through a drum as large as the steam-space of the boiler in which the same quantity of steam would ordinarily be generated, the water will be separated by gravity, the same as in the boiler itself. In most cases the pipes themselves act as drums. In any case, by a proper application of principles, it is possible to transmit steam to as great distances as any other fluid. The actual maximum distance must be governed by commercial considerations as to relative cost of piping and stations. To make steam efficient, then, it is necessary only to maintain the desired pressure at the ends of the lines, and this depends on the size of the pipes, and the loss of pressure that can be permitted.

As mineral wool was non-combustible, quite permanent, when kept dry and not subject to friction, and withal could be manufactured quite cheaply, it was fixed upon as the material to insulate the pipes. In the majority of cases the pipes were suitably supported in the bottom of a trench, brick walls built up at either side, and covered with planking and roofing material, so as to leave a space of from three to four inches about the pipe on all sides, in which mineral wool was

placed in bulk. The result of this method of covering has been that with nearly five miles of large pipe, also about seven miles of smaller pipes used as services, all under steam continuously days, nights, and Sundays, there is required but one hundred and fifty horse-power, each of thirty pounds of water per hour, to supply the condensation in the mains. The mains vary from sixteen inches in diameter to six inches, and the services are mostly three inches in diameter. This loss is so small, as has been previously stated, that it does not affect seriously the commercial problem of the transmission of steam. The water of condensation, however, though limited in quantity, must be properly provided for. If in all cases steam could be transmitted at slow velocity in a large pipe, graded so as to have a slight descent *away from* the source of supply, the water in the steam would separate by gravity, and trickle along the bottom of the pipe, the size of the stream of water gradually increasing until means were provided to permit its escape. By taking the steam from the top of such a pipe, and arranging to blow out the water at intervals from the bottom, the length of the pipe could be continued indefinitely, no inconveniences would result except the loss of pressure due to the distance, and the steam at any point would be as dry as though it came from the boiler direct. This ideal state of facts is accomplished as nearly as possible in practice. Steam must, however, at times be carried up a slope instead of down, and frequently the pipes must have undulating grades to correspond substantially with those of the surface of the ground. When the movement is up a slope, the water of condensation is to a greater or less extent entrained by the current of steam, which is particularly the case when the steam is moving at a high velocity. In practice, the up grades in the direction the steam is transmitted are made as sharp and as short as possible; and beyond the summits, the down grades, in which there is a natural separation of the steam and water, are made easy and long. This desirable arrangement cannot always be carried out; the street obstructions are frequently so arranged that the pipe can only be laid in undulating grades corresponding more or less to those of the surface. In all cases arrangements are made to trap out the water of condensation at the bottom of every dip of the pipe, so that the current of steam passing onward and upward has no more water to contend with than is condensed in the portion of the pipe to be passed over. The water

is removed automatically by a steam-trap, and returned to the boiler-house by another system of pipes, called return water-pipes.

The expansion of small pipes is generally provided for by means of bends and offsets which will spring sufficiently. This method in its simpler form is applicable to short lengths only, but if the arrangement be well studied, pipes of any length may be laid on this system. For instance: if it be desired to run a pipe from one end of a long building to another, it may be accomplished by crossing and re-crossing a sufficient number of times. No known rules for this kind of work are formulated. The workman is supposed to make the offsets of such number and with such lateral lengths that expansion will not strain the joints. Frequently, however, insufficient attention is given to this matter, and leaks are developed at important fittings, which it seems impossible to keep in repair, and the work can only be made satisfactory by changing the system to suit actual conditions. A modification of the offset system, with what are called "swinging elbows," forms a much safer method of providing for expansion, but is less used, as more fittings are required, and some little study is necessary to adapt the work to the straight lines and flat grades necessary in a building. It is, however, a very desirable way of laying long pipes of limited sizes under ground and elsewhere where the grade can be changed as required.

Stuffing-boxes, or slip-joints, are frequently used on long lengths of pipe to provide for expansion, though generally on large pipes only. This system answers very well for water-pipes, or where the steam pressure is low. With high-pressure steam the packing has to be very compact to resist the pressure, and great care, and some considerable expense, is required to keep the stuffing-boxes in order, and prevent them from leaking.

The speaker explained that, when he was called upon to design a steam system, it appeared to him desirable to avoid the necessity of using slip-joints, with their leaks and expense in care and attention, and it was readily seen that the elaborate system of offsets was not practicable. Experiments were therefore commenced, with modifications of what are known as diaphragm joints, which showed that such joints were more satisfactory the thinner the metal used in the diaphragms, so that finally a diaphragm expansion-joint, called a variator, was developed, in which the diaphragm was of copper less than one-six-

teenth of an inch thick, corrugated concentrically, and supported on radial backing-plates, which prevented the diaphragm from being distended to rupture by the pressure. A double variator has two diaphragms, and provides for expansion from two fixed points on either side, fifty feet away. The single variator has but one diaphragm. The services are taken from the bodies of these variators. The outlets are provided with flanges, but are plugged in the first instance, the plugs being removed as required with steam pressure in the mains by bolting a valve to the flange and removing the plug through it by means of a special tool. The stems of the valves are extended nearly to the surface of the street, and may be operated through suitable openings in castings placed between the paving-stones. At regular intervals of about fifty feet the pipes are connected by means of ball-joints, which enables their direction to be changed slightly, and takes out all strain. Both the ball and plain flanged joints are made tight by the use of gaskets of thin copper corrugated annularly, which squeeze into every irregularity of the surface, and make absolutely tight work, even without the use of paint or putty. Pipes of six inches in diameter, or less, are screwed into the fittings. Larger pipes, of which some have been used as large as sixteen inches, are expanded into the flanges and fittings. The ends of the pipes abut against shoulders, and the faces against which the expansion takes place are slightly dovetailed. The variators are provided with flange-boxes which cover the connecting flanges, and terminate in cylinders of metal, which are built in the brick work surrounding the variators. The bodies of the crosses and tees are made globular to better resist the strains to which they are subjected. Wherever a valve is placed in a pipe, or a line is terminated, heavy anchorage castings are abutted against the flanges of the pipes, and masonry built against castings with wings well spread out to engage with as much of the surrounding soil as possible, and thereby hold the pipes and fittings rigidly in position. Two lines of mains are run, one for steam, the other for the return-water of condensation. Generally, the latter main is laid lower than the other, so that the outlets of the two mains will pass each other. On Fifth Avenue, where there is rock excavation, with large water-pipes lying at one side, the bottoms of both mains are put on a level, and the side outlets take out below the level of the mains through what is called a drop-cross.

The traps used are of the bucket variety, with valves of different kinds, operated directly by a float, or through the intervention of levers, according to the size of the trap. The meter which was adopted after considerable investigation, called a rate meter, allows the steam to flow through rectangular openings, governed by a valve operated by a weighted piston, balanced on the difference of pressure between the incoming and outgoing steam, the effect of which is that the steam flows through the orifice at a constant difference of pressure, the size of the orifice being regularly registered on a broad paper strip traversed by clock work. The result is a diagram showing at any time in the day the quantity of steam used at that time, and the total quantity may be obtained by integrating the chart. These meters and regulating-valves are placed in the pipes leading from the streets to the buildings, and arranged with shut-off and pass-by valves so that any part of the apparatus may be put in order without stopping the supply of steam to the building. One great difficulty in dealing with consumers has been that the janitors and others would waste the steam by keeping it on at night, but this particular form of meter enables the company to show the consumers when steam is used.

The lecturer then described a watchman's tell-tale system, in which a valve in the pipe leading to the consumer was connected electrically with a watchman's box on the exterior of the building. The watchman, being provided with suitable recording apparatus on his person, visited the several boxes in succession, and by sending an electrical impulse from the watchman's box into the valve received in turn a record which could be interpreted at the office to show whether or not the valve was open. This apparatus was used while suitable meters were being devised and perfected.

Speaking of the causes and prevention of water-rams, the speaker said that, if steam be admitted to the top of a vessel partially filled with cold water, condensation will take place until the surface is somewhat heated, and this, in connection with a cloud which forms above the surface, retards rapid condensation, so that in due time the full steam pressure can be maintained above water cold at the bottom. This phenomenon is not an infrequent occurrence in boilers in which the circulation is defective. It is, therefore, perfectly safe to heat up any vessel containing cold water if the steam can be admitted from the top upon the surface of the water, and so maintained. If,

however, steam be blown in below the surface of the water, a bubble will be formed, which will increase in size until the surface becomes sufficiently extended to condense the steam more rapidly than it can enter, when a partial vacuum will be created, the bubble will collapse, and the water flowing in from all sides at high velocity will meet with a blow, forming what is called a water-ram. In blowing steam into a large vessel, these explosions occur in the middle of the mass, and create simply a series of sharp noises. If, however, steam be blown into a large inclined pipe full of water, it will rise by difference of gravity to the top of the pipe, forming a bubble as previously stated, and, when condensation takes place, the water below the bubble will rush up to fill the vacuum, giving a blow directly against the side of the pipe. As the water still further recedes, the bubble will get larger, and move farther and farther up the pipe, the blow each time increasing in intensity, for the reason that the steam has passed a larger mass of water which is forced forward by the incoming steam to fill the vacuum. The maximum effect generally takes place at a "dead end," as it is called, or where the end of the pipe is closed. Even if the water does not originally extend to the "dead end," if the pipe near it be once filled with steam which has bubbled through water on its way to that point, there may be sufficient cold metal to condense it, so that collapse will take place on the same principle as before, and the whole mass of water in the pipe be driven by the incoming current of steam against the end, sometimes with tremendous force, the effect being to cause leaks, and sometimes rupture the pipe or break out the end connections.

He explained that water-rams may be prevented either by draining the pipes or by opening one end of the pipe and introducing steam quickly and in large volume at the other, thus forcing the water ahead of the steam so rapidly that bubbles cannot be formed, and rams not take place. The latter plan requires nerve and judgment, so an ordinary workman cannot be trusted to undertake it.

In concluding, the lecturer stated that there is a field for another lecture in a popular view of the question relating to the uses to which steam from the streets can be put, and the advantages of this method of supply. It will be understood that steam-engines of all kinds and sizes, in any location, from cellar to garret, can be operated to drive shops, furnish electric light, pump water, and the like, and that heat-

ing, either with live or exhaust steam, can be done on any scale; but it is also true that nearly all the *cooking* of a family can be done by steam. Nothing is lacking, in fact, but sufficient temperature to brown bread, and put the finishing touch, as it may be called, upon broiled meats. Meats may be cooked perfectly with steam heat, but they cannot, in the open air, be so highly heated as to give the particular aroma which pleases the taste. Meats of all kinds can be roasted in an oven jacketed with steam more perfectly than in one heated directly by fire, as the juices of the meat are kept in, and, becoming heated, aid in cooking the entire mass evenly and thoroughly. Many large restaurants do all their roasting in steam ovens. Boiling of all kinds is very simply performed in jacketed kettles. An attaché of the New York Steam Company has recently made an invention whereby, by planing the top of a steam table and the bottoms of the vessels to be heated and using simple clamps, stews can be made and water boiled in vessels not jacketed with steam, the heat being transmitted from below, and the rapidity of heating, or violence of the ebullition, controlled simply by tightening or loosening the clamps. With steam-stoves fitted with these various devices, and having in connection therewith a small gas-stove for finishing the broiling of meat, and perhaps a gas attachment to the oven to brown the bread and cake, housekeepers will be provided with a great boon. With the exceptions named, which do not form a large portion of the work, every operation can be performed by simply regulating a steam valve. By these means the objectionable features of handling coal and ashes will be entirely removed, and provision for doing most of the cooking, as well as complete facilities for heating water, and, in winter, for warming the building, be provided "on tap," so to speak, the same as gas and water.

Thus the sun's energy of ages past, stored in luxuriant vegetation, and buried with it beneath débris due to cosmic changes, may now be redeemed from the bowels of the earth as coal, transmitted to a distance as steam, and bring sunlight to the household by lightening domestic labor. Power, heat, and even actual light, may be obtained, and manufactures promoted in most inaccessible and contracted places; and, gentlemen, one more subject is now available for the exercise of the talents of the engineers of the future in their

efforts to advance still further the comforts and civilization of mankind.

The lecture was illustrated by numerous views, thrown on the screen, of the variators, meters, traps, valves, crosses, tees, special fittings, etc.

A vote of thanks to the speaker for his very instructive paper brought the meeting to a close.

MEETING 345.

The Roadways of New Mexico.

BY HON. CLARENCE PULLEN.

The 345th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 11th, at 8 P. M., Prof. Geo. L. Vose in the chair.

After reading the minutes of the previous meeting, the chairman introduced Hon. Clarence Pullen, ex-Surveyor-General of New Mexico, who read a paper on "The Roadways of New Mexico."

Mr. PULLEN said: In order to speak understandingly of the roadways of New Mexico, it is necessary first to describe some of the natural features and present conditions of that interesting but generally little-known part of the United States. New Mexico, which was successively an ultramarine province of the Spanish crown, a State of the Mexican republic, and a territory of the United States, lies between north latitude 31° 21′ and 37°, and between west longitude 103° and 109°. Its shape is generally rectangular, its average length north and south being 362 miles, and its width 335 miles. Its hight ranges in round numbers from 4000 feet to 12,000 feet above the sea level. One-third of its area is composed of a series of level *mesas*, or table lands, beginning at the east slope of the Rocky Mountains, and breaking precipitously, one down to the other, to the plains of Texas. The west two-thirds of New Mexico lies upon the ridge of the continent,

the Rocky Mountains, which here divide into parallel mountain chains, running north and south, between which are high, wide valleys or plains. These mountain chains are cleft in places by steep and narrow cañons, and to them all east and west routes of common travel must necessarily conform.

The rivers of New Mexico flow from the mountains clear, cold streams, the waters of which become warm and alkaline soon after reaching the plain, and, in many cases, during the dry season, disappear from sight, percolating the sand beneath the river bed. These rivers are liable to heavy and sudden floods, arising from rains or waterspouts in the mountains. When on the plains the day is clear, with no sign of storm, a flood from the mountains will sometimes invade the dry channel of a stream, coming on, a vast wave, rolling over and over in front, like an undertow, and carrying with it everything movable that may lie in its way. In freighting with wagons and animals in New Mexico, it is the practice, on coming at night to a stream that is to be crossed, always to go into camp on the further side, as the next morning may find it impassable. The Rio Grande, or, as the New Mexicans call it, the Rio Grande del Norte, rises in the Mountains of Colorado, and flows south through New Mexico, about midway between the east and the west boundaries of the territory. As it leaves the southern border of New Mexico it becomes the boundary between the United States and Mexico. It lies in a wide, sandy valley, and, measured in its windings, is about 1500 miles long. It is wide and narrow, shallow and deep, in different places, full of quicksands, and subject to sudden floods and changes of channel. A few years ago, the inhabitants of the considerable town of Mesilla, in Southern New Mexico, awoke one morning to find the river flowing on the west of them instead of as hitherto on the east. In traveling along the Rio Grande Valley one can easily trace in the depressions of the earth's surface the river's old channels. Under these conditions of the river system it is evident there can be in New Mexico no extended transportation by water. The location of any traveled way must, however, be controlled by the necessity that there be on its line an available water supply for the physical needs of men and animals, and this fact must be especially considered in establishing routes in an arid country like New Mexico. Thus its roads are naturally found along the valleys of streams, or elsewhere so located as to

encounter, even at the sacrifice of directness, a watering place at least once in an average day's journey.

The position of streams, springs, and wells is the primary element in the determination of the roadways of New Mexico.

The traveled ways of New Mexican towns represent three different races and civilizations. Those of the Aztec, or Pueblo Indian, cities are mere haphazard paths or openings, left for convenience as successive houses were built, but with no reference to a pre-arranged method; or in the cities of more antique type, as Taos or Zuñi, narrow alleys or passages between houses so closely united as to be practically one vast building. The Pueblo Indian travels on foot, and transports all freight on the small pack animals of the country, and so needs none of the more extended facilities rendered necessary by the use of vehicles.

The Mexican towns, which greatly predominate in the territory, are built in the usual Spanish fashion, the houses fronting solidly upon a plaza, or public square, from each corner of which two narrow streets lead out into the open country. But little attention is given to the building or mending of roads, and the streets and plaza are usually in the shape to which they have been reduced by the action of wheels and foot travel upon the natural surface, or by the washing of rains. The streets leading from the plaza meander in conformity with the configuration of the ground, and beyond the houses of the town are mere mountain or prairie trails. The houses of a Mexican town are one story in hight, and have verandas facing the streets or plaza. The walls are of great thickness, and in the older houses extend above the flat roof, forming a parapet available, should necessity arise, in the defence of the establishment. The almost invariable building material in New Mexico is adobe, a tough clay, which, mixed with grass or straw, molded into large bricks and dried in the sun, makes, in so dry a climate, an available and enduring structure. The walls of corrals, gardens, and cultivated fields are made of adobe. The larger Mexican houses are built about a court, called the *placeta*, often of considerable area, and upon which open inner doors, windows, and verandas. This court is entered from the street by a passage or archway, closed by double gates. The whole arrangement of the establishments of the wealthier Mexicans illustrates the Spanish-

Moorish instinct of seclusion and exclusiveness, and but little of the inner life of the household is indicated to the passer-by on the street.

Those parts of the Mexican towns, or rather additions, populated by Americans from "the States," have much the appearance of the towns in any of the newly-settled States and Territories. Wood, stone, and burned brick are more used as building material than adobe, and the houses are of modern construction. The streets and avenues are wide and regular, and are provided with the necessary bridges and culverts. There is a due proportion of public squares, which are often enclosed and laid out as little parks, with grass, trees, and foot-walks. The great sanitarium of the Atchison, Topeka, and Santa Fé Railroad Company encloses a park of fifty acres, adorned with trees, lawns, terraces, flower-beds, a deer-park, rustic houses, and fountains, and traversed by paths and driveways. The mountain stream — the Rio de las Gallinas — that winds through these grounds is here crossed by four foot-bridges, while along its valley a carriage-road leads up into the precipitous recesses of the wild and picturesque Gallinas Cañon. Generally, through the mountain region of New Mexico the cañons are penetrated by trails usually available for carriage riding, and all could with little labor be made into good driveways. In places inaccessible to vehicles, foot or "burro" trails cross gaps in the ridges, or wind against the steep sides of mountains.

The first road-makers of New Mexico were the buffalo, which, in their migrations, sagaciously picked out the best ways and the best fords. The roadways subsequently made by man have seldom been able to improve in location the routes selected by these "hump-backed oxen of the prairie." Later came the Pueblo Indians, a race akin to, or the progenitors of, the Aztecs. These people having at an early period no beasts of burden made only footpaths. Living for safety on eminences difficult of approach, their narrow paths lead up to their homes often against the faces of seemingly inaccessible cliffs. The Apache Indians, contemporary with the Pueblo, but of a different class ethnologically, and with ungracious traits, have defined and peculiarly marked trails, which are separate and distinct from the ordinary routes of travel. These footways have the characteristics of the path of a beast of prey, being narrow, and, in long grass, almost invisible, but have been deeply worn, in the centuries, by the feet of moccasined Apaches and unshod ponies. They lead to points of

observation and vantage, but are so located as to leave the travelers thereon as much as possible in concealment. These paths are indicative of the predatory character of their makers, and are carefully scrutinized in times of Indian troubles.

In 1536 Cabeza de Vaca, who had been shipwrecked nine years before on the coast of Florida, entered New Mexico on the east, and traversed the southern part of the present territory. In 1541 Francisco Vasquez de Coronado, the governor of New Galicia, made an expedition into New Mexico with four hundred Spanish and eight hundred Indian soldiers. He went north to the Indian city which was on the present site of Santa Fé, and then, in quest of the "seven cities of Cibola," and their reputed inestimable riches, he crossed the plains to the eastward, and actually traversed the present State of Kansas. In the rooms of the Historical Society of Kansas is shown a map of his route, which is practically identical with the location of that famous highway of prairie commerce known during the present century as the Santa Fé Trail.

Two great trails have, during three centuries, connected Santa Fé, in New Mexico, with Mexico, one leading down the Rio Grande across the Jornada del Muerto (Journey of Death) and south to the city of Mexico, the other leaving the Rio Grande and lying southwest across the plains and mountains through the Apache Pass, thence to Guaymas, in Sonora. The journey to and from the City of Mexico from Santa Fé formerly occupied five months.

The Santa Fé Trail from Independence, Mo., to Santa Fé may be considered to have been fairly established in 1822, when a party of thirty-five men, with pack horses, carrying $15,000 worth of goods from St. Louis, Mo., went over it to the capital of New Mexico. In succeeding years wagons took the place of pack animals. Thereafter, the tide of a great commerce never forsook this highway until it was supplanted by the road of the iron rails, and it was strung from one end to the other with the white-topped wagons of freighters. It is now much used as a wagon road, but its great commercial importance is a thing of the past. Where this trail crosses the Raton Mountains, "Uncle Dick" Wooton, an old frontiersman, and companion of Kit Carson, built a turnpike road, and charged all passing wagons a dollar apiece, which yielded him for many years a princely revenue.

The first railroad to enter New Mexico was the Atchison, Topeka,

and Santa Fé, on Dec. 7, 1878. There are now four railroads in the territory, viz., the Atchison, Topeka, and Santa Fé, the Denver and Rio Grande, the Atlantic and Pacific, and the Southern Pacific, with a total mileage within the territory of about eight hundred miles. In places extraordinary precautions have to be taken for the protection of the track against floods. The extraordinary changes in channels of the rivers is a cause of trouble, and, by a cloud-burst in the mountains, a torrent will sometimes sweep down against the track in a place where no water-course has previously been indicated. All of the New Mexico railroads are substantially built and well managed.

Mr. Pullen gave a description of the opening to Las Vegas of the Atchison, Topeka, and Santa Fé Railroad, and of a ride in the first train over the completed route, and related some stories of the overland stages. At the close he exhibited and described various articles of Apache and Navajo Indian manufacture, as war-clubs, baskets, a lasso, head-gear, and blankets.

MEETING 346.

Labor Differences, and Arbitration.

BY MR. JOS. D. WEEKS.

The 346th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 25th, at 8 P. M., Mr. Edward Atkinson in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Mr. Jos. D. Weeks, of Pittsburg, who read a paper on "Labor Differences, and Arbitration."

Mr. WEEKS said: I am to discuss with you tonight one phase of the most important and most perplexing of human problems, — the Labor Question. Though this is no new problem, it is thrusting itself as never before upon our attention, and with an imperiousness that is new is demanding our consideration. It comes to us in our

homes, in our workshops, in the halls of legislation, and even in the temples of the Infinite. With an importunity that makes no refusal, it demands and will have answer. What shall the answer be? What shall the manner of the answer be? Shall the best answer we have to give be strikes and lock-outs? Shall the manner of the answer be "with confused noise and garments rolled in blood"?

The particular phase of this problem to which I desire to direct your attention, which is also in its practical relations the most important one, is the constantly recurring differences between employers and employed, and the best method not only of settling them but of preventing their occurrence.

While the present relations of employer and employed continue, differences will of necessity arise between them. At many points their interests and opinions diverge. These differences will at times grow into disputes, and may result in the industrial strife that is in strikes and lock-outs. Just here let me emphasize the fact, too often overlooked or forgotten, that strikes and lock-outs are not the beginnings of industrial strife. Its source is in these differences, and industrial peace, with all its blessings, is best secured not by settling strikes and lock-outs when they arise, but by preventing or settling these differences between employer and employed before they have time to grow into strikes.

To discover the best method of settling these differences, and of preventing them from becoming disputes, is an imperative duty. To settle these disputes, if unfortunately they arise, without the massing of forces and the shock of conflict, without driving strong men to sit hollow-eyed and despairing, and hounding women and little children into the very shadow of death, is demanded for our own safety and for the stability and perpetuity of our institutions.

And may I suggest that the search for this method should be without any anxiety to preserve intact what have come to be regarded as economic laws. Of the authority of many of these laws, and of the obligations they impose upon men, there are grave doubts. There are higher objects in life than the preservation of what, at best, are only "expressions of an observed tendency in human affairs." There are no economic laws that are eternal and commanding. On the contrary, there are forces in the domain of industry that regulate and modify, and even at times abrogate, these so-called economic laws.

Beyond this there are obligations laid upon mankind by an authority so commanding that we do well to hesitate before we dare refuse His mandate, even to preserve unbroken these so-called immutable economic laws. No laws, no customs, no theories, are so sacred that they may not be made away with if they stand in the way of this higher law.

Nor can any method of settling these differences have any permanent value that ignores or refuses to recognize conditions which actually prevail, or to give full consideration to forces which experience proves are potent. Radical changes have taken place in the theoretical and actual relations of employer and employed to each other, and of both to the State and to society. There have also come to labor, with its growing power and intelligence, a larger liberty and greater freedom of action and combination. The old methods of dealing with the questions that affect its interests and relations, or methods that are based upon the old conditions and old views, are no longer effective, nor will they be longer tolerated. No more serious error can be committed in settling and applying methods for the prevention or adjustment of labor differences than a refusal or failure to recognize, with all it involves, the new relations of labor to its environment and the drift of thought and action among workingmen. Such an error is fundamental and vital, and so long as it remains uncorrected industrial peace is impossible. It should be frankly recognized and freely acknowledged that employer and employed are independent equals, uniting their efforts to a given end, each with the power, within certain limits, to determine his own rights, but not to prescribe the duties of the other. The employer has no more right to dictate or even decide how labor shall seek its interests than labor has to dictate to the employer.

Before asking what method gives promise of most surely and swiftly settling these differences, and of most effectually preventing their occurrence, it will be well to ascertain their precise character, that we may the better judge of the probabilities of the success of any method that may be proposed. It will be found, I think, that they exhibit marked distinctions, and it will also be found that a failure to recognize this has led to many abortive and costly experiments.

Though the specific questions involved in these differences are

well-nigh innumerable, they readily group themselves into three classes: —

First. Differences as to future contracts.

Second. Disagreements as to existing contracts.

Third. Quarrels over some "matter of sentiment."

By contracts are meant not only formal agreements, but customs of the trade or shop, or methods of work or administration that have the force of contracts. Under quarrels over "matters of sentiment" would be included quarrels growing out of the wounded self-respect of the parties to these differences, or involving their personal relations and ideas of fairness, justice, personal rights, or good faith.

These three classes of differences have distinctly marked characteristics. The second relates to work actually done and rights that have accrued; the first to work to be done and the basis on which it is to be performed, and involves, if I may be allowed the expression, the fractional right of each party to production in the results of their joint efforts. Now, it is evident that a method that may be adapted to the settlement of one of these two classes may utterly fail when applied to the other, and may be still less adapted to the third class, which involves no property rights at all, but only "questions of sentiment" that are not amenable to the rules or considerations that apply to property.

While it thus appears that there are marked distinctions between labor differences, it will be found that the chief causes of these differences are questions as to rates of wages. It is here that the interests of employer and employed begin to diverge, and it is concerning these questions that differences most frequently result in labor contests. It will also be found that many questions which are not primarily wages disputes have a direct bearing upon rates of wages, and are important only because of such bearing.

In an inquiry into the strikes and lock-outs of 1880, which I made for the Tenth Census, out of a total of 813 labor contests investigated, 582, or 71.59 per cent were caused by differences as to rates of wages. Of these 582 contests 86 per cent were for advances, and but 14 per cent against reductions.

So also it will be found that these wages disputes, with hardly an exception, have regard to the future. Fully 90 per cent of these

differences relate to work to be done. Of the 582 wages contests of the Census Report, but one concerned the past.

It will appear, therefore, that the chief need in seeking a method that shall prevent or settle labor differences is to find one that shall be effective in fixing the terms upon which work shall be done in the future, and which shall at the same time be adapted to the removal of these other causes of disagreement or the adjustment of the disputes that result from them.

While the methods that have been suggested or employed for settling these differences, and the disputes that have arisen from them, have presented a great variety in their details, they may be grouped into four classes: —

First. Competition, or *laissez-faire.*

Second. Legislative enactments.

Third. Strikes and lock-outs.

Fourth. Arbitration and conciliation.

To the first three of these the limit of time at my disposal will permit but a brief reference.

Probably no method for the settlement of labor differences has been more persistently or ably urged than the first of these, — competition. The advocates of this method assert not only the efficacy of this law or force, but that its action is inevitable as well. They insist that all labor differences and disputes not only should be, but ultimately must be, left to settle themselves by a free competition between the individuals interested, without any attempt on the part of the State or other individuals to modify or control the result.

Recalling the classification made of these labor differences, a moment's consideration will make it evident that there is a large class of differences which, from their very nature, competition is powerless to decide. Most if not all of those arising under the second and third divisions are of this number. How, for example, can competition define the meaning of an ambiguous term in a contract, or settle what is the custom of a trade or shop? How can *laissez-faire* settle any of these quarrels over matters of sentiment? It might, perhaps, define the meaning, or settle the custom for the future; but that is not by any means determining what they were. It might drive from their employment the workmen who raised these questions and substitute others, but a change of employés is not settling these differences.

But, in addition to this inability arising out of the nature of the questions submitted for decision, such competition as this method contemplates is, under existing conditions, at times neither possible nor desirable. There are menaces to the stability of society in its prevalence. It is the method of contest, not of judgment and reason. There are obstacles in the way of its action that grow out of all the relations which the members of industrial society hold to each other. There are forces in this society which at times are more powerful than the assumed individual impulse towards the best market, which regulate and modify and even thwart competition.

Further, the tendency of competition, acting without restraint or guidance, is not to right economic wrongs or establish justice. I need hardly say that the end sought is not simply a solution of these vexed questions, but one that shall be just and equitable. Such a solution is not, as a rule, the result of the dealings between an individual employer and an individual workman. Realizing this, and also that competition is destructive, and that the highest welfare of a people is not always in buying its calico cheap, labor is refusing to deal as individuals with its employers, and is insisting upon its right of combination, and that these combinations shall have a part in fixing the rewards of labor, and the conditions upon which work shall be done. I need scarcely suggest that its demands are being complied with.

As to the second method,— legislative enactments,— it is now generally conceded that legislation relative to labor questions of the iniquitous character that prevailed in England for four centuries and a half — from, say, 1349 to 1802 — is a failure. This legislation sought chiefly to regulate or fix wages by act of parliament, or the decisions of magistrates, and to prevent combinations of labor. The experience of these centuries has taught not only the injustice and injury to all classes of such attempts, but the futility as well.

The failure of this legislation, however, cannot fairly be urged as conclusive against all legislative interference with labor questions. There has grown up in the last few years, especially in England, a body of legislation of a very different character from that referred to, and treating of subjects with which legislation can legitimately deal. Among these laws are those regulating the hours and conditions of employment in certain dangerous and unhealthy trades, as mining and

match-making; those defining and extending the liability of employers in cases of accident and death; those regulating, and, in many cases forbidding, the employment of women and children; those providing for the inspection of factories, workshops, and mines; those forbidding truck, regulating the frequency and place of payment of wages, the hours of labor, the methods of screening and weighing coal, etc.

All of these laws relate to subjects that have been prolific causes of labor differences, and to the extent that they regulate or deal with them, to that extent, at least, they reduce or remove the liability to discontent.

As to the wisdom and right of most of these laws there is, on the whole, a general aggreement. Some who are concerned as to the fate of certain theories, and others with whose interests they seem to conflict, condemn them, and hold that in all or most of these matters the individual is amply able and should be left to protect himself. On the other hand, not only employés and the wisest of modern economists, but even employers are coming to realize that these laws are not only just but that they are wise as well. Many causes of dispute have been removed, and labor has been made more efficient, more intelligent, and more contented. The fear as to the evil results that would ensue has not been justified, but, on the contrary, benefit instead of injury, strength instead of weakness, have been the consequence.

The method of dealing by legislative enactments with questions such as those just mentioned is, we think, on the whole, a safe, wise, and effective one. The manner, the occasion, and the use of the law must always be somewhat in doubt, and at times raise most serious and complicated questions. Mistakes will be made, but these will soon manifest themselves and be corrected. The difficulty will not be with the method, but with its application. As human judgment is, after all, the ultimate resort and the controlling influence in whatever method is adopted, it is fair to presume that in those matters which experience has shown to be legitimate subjects of legislative enactment, the judgment of parliaments and legislatures, elected as those of the present day in English-speaking nations are, will be as correct as that of individuals moved by a desire to procure wealth.

As to the third method,—that of strikes and lock-outs. While this method is often appealed to for the settlement of these questions

between employer and employed, I have yet to learn of any advocate of the system, except as a last resort, and when other methods fail. I know that the history of strikes — and even recent ones — shows that folly and passion, not to say baser motives, have guided men both into and through these contests, but it still holds true that neither empoyer nor employed deliberately advocates this method as the ruling one. The leading trades unions incorporated into their fundamental law their decided objections to strikes, and decline to enter upon them or to permit their executive authority to recognize as valid those that may be undertaken by individuals until other methods have been tried and exhausted. These men know by bitter experience the brood of sorrows that accompany and follow these strikes. They have brought hunger, misery, debt; have broken up homes, severed long associations, forced trade to other localities, and driven men and women into the very shadow of death; and yet men, knowing that all of these possibilities are before them, will deliberately enter upon strikes, will cheerfully bear all these privations, and, what is more remarkable still, in many instances the wives of the strikers, upon whom the misery falls with the most crushing force, will be the most determined in their prosecution. It would seem that there must be some reason for this, and it will be found that strikes are not wholly wrong, and that even unsuccessful ones are in many ways advantageous to the strikers. Labor has had to fight for every advantage it has gained, and, though it is often defeated in its struggles that are called strikes, it has not only learned in these contests how better to wage future battles, but has so impressed employers with its strength that it has made them shy of encountering antagonists constantly growing more formidable.

They have also made employers more willing to examine into the causes of complaint, and to meet their employés in a spirit of fairness when differences arise. The most hopeful indication of modern industrial society is the great increase of mutual respect and good-will between employer and employed, as well as a greater regard on the part of each for the rights of the other. To this result strikes have contributed in no small degree. They have also asserted the right of combined labor to deal with combined capital, and have denied the claim that the true labor market was found in the "hig-

gling" of capital with all its power and one individual workman with all his weakness and necessities.

And yet this method is one of force, and does not after all decide anything except that one party to the contest can hold out longer than the other. When the battle has been joined and the contest decided (a decision very rarely the result of judgment and reason, but one forced by other considerations), what has been gained, and what decided? A battle has been fought, a victory won, or a defeat suffered. That is all. And what is a victory won under such circumstances worth? For what does it count in the light of our civilization? Have six thousand years of toil, with this labor problem ever pressing, found no better judge, no kindlier umpire than brute force? than hunger and greed? At the end of every strike or lock-out there is always one practical problem that loudly and urgently demands a solution,— to find out some means by which the existing organization of industry, not some system yet to be devised, can be made to work without these wasteful contests that are so frequent as to seem well-nigh an essential part of the system. The future may be hopeful, may have in it the perfect solution of the labor problem; but we need a system that shall take labor as it is, and capital as it is, and their relations as they are; that shall prevent their differences from becoming disputes; that shall settle contests if they arise, or at least shorten their duration, and mitigate their horrors; that shall give passion time to cool, and permit reason to assert its sway, and thus give time and opportunity to discuss the future organization of industrial society, in which there shall be no place for strife.

I believe that arbitration and conciliation is such a system. Not only that, I believe that it is the best one possible; the only effective one yet devised for adjusting the relative rights of employer and employed under the present constitution of industrial society. Under its methods there is an opportunity for a calm and intelligent consideration and discussion of the intricate and troublesome problems that grow out of the relations of employer and employed. Indeed, it is the only method yet devised which promises decisions of these vexed questions that shall be even approximately reasonable, just, and right.

It brings to the consideration and discussion of these questions not the information, perception, and judgment of one class only which are apt to be imperfect, clouded, and biased, but the combined intelli-

gence, information, and judgment of both employer and employed, standing at different sources of information, and looking at these questions from different points of view. This method takes cognizance of existing conditions; recognizes the perfect equality of employer and employed; commits the prevention and settlement of these differences to the reason and judgment of both, not to the selfish impulses of one; refuses to recognize force; does away with the necessity and excuse for strikes and lock-outs; permits due weight to be given to economical forces, and due consideration to any action their presence and power demand; furnishes the nearest approach to a free, open, labor market that has yet been established; in a word, it meets better than any method yet proposed the conditions necessary to a satisfactory and intelligent discussion and settlement of these questions, and offers far greater surety that justice will be done and equity and peace established than does any method that relies upon blind, unreasoning, undiscriminating law or force.

The remainder of the time at my disposal will be given to a discussion of this system.

Though the terms "arbitration" and "conciliation" are jointly used to name the system of dealing with labor differences by boards or committees made up of both employers and employed, these words by no means represent the same thing. "Conciliation" is properly applied to attempts to settle or prevent labor differences by conferences between the parties in interest, or their authorized representatives, these conferences having no power to reach a decision except as the result of mutual agreement. "Arbitration," on the other hand, implies a conference and agreement, if possible; in case no agreement can be reached, then the matter at issue is to be referred for settlement to one or more persons whose decision is morally or legally binding upon both parties. In conciliation there can be a mutual agreement only; in arbitration there may be a formal and binding judgment.

Recognizing this distinction between arbitration and conciliation, the bodies formed for applying this method to labor differences assume two forms: —

First. Boards or committees of conciliation which employ conciliation only.

Second. Boards or committees of arbitration and conciliation, which employ both arbitration and conciliation.

While conciliation committees, usually by informal rather than by formal and organized action, have had some measure of success, the best and most effective work has been done by arbitration of boards. It will be found that even conciliation has been most efficient when connected with arbitration. It is true that arbitration recognizes conciliation, and avoids the umpire if possible, thus conceding the greater desirability, if not superiority, of conciliation, and it undoubtedly is desirable that the parties themselves shall agree, if possible, but the system would be inadequate to the demands upon it did it not provide a method of reaching a decision in case, as frequently will happen, that the parties cannot, or will not, unite in one.

It will be found, therefore, as a rule, in the practical workings of this system, that arbitration and conciliation are united, conciliation dealing with minor matters or questions of detail, or those affecting the individual or small bodies of men; and even with broader questions, when decisions can be quickly reached, concerning such questions, opinions are not as decided nor as tenaciously held. But when a question arises that affects in a serious degree the whole trade or large bodies of men or large amounts of capital, then the method of conciliation — of mutual agreement — is usually of little avail, and the umpire is called upon.

In addition to the division of these bodies, based upon the distinction between arbitration and conciliation, there is a still further classification, based upon their duration and the continuance of their operations. These boards or committees may be —

1. Temporary. That is, organized in an emergency, or in the face of an impending difficulty, possibly in the midst of a strike or lock-out, and passing out of existence as soon as the special work they were organized to do has been accomplished, or their efforts have failed.

II. Permanent and systematic. That is, having a continuous existence, and dealing constantly and systematically with all questions as they arise between employers and employed in the works or trade or district which the board or committee represents.

While temporary boards or committees may and do settle questions that are referred to them, it is evident that the chances are against

them. When a labor war is imminent or in progress, there is usually no place for discussion, and the decision of boards organized at such times is accepted by one party or both under duress, and is apt to be, like the board itself, temporary.

Many of the failures of arbitration and conciliation, and much of the discredit with which it is regarded, have grown out of the incompetency and shortcomings of these temporary or emergency boards. They ignore entirely what is regarded by its advocates as the most essential feature of the system,— prevention, not cure. It cannot be too often pointed out that the demand in connection with labor differences is not for a method that shall settle strikes, but for one that shall prevent labor differences, either by removing their causes or by promptly settling them before they grow to disputes. It is the claim of the advocates of arbitration that permanent boards of arbitration and conciliation, with their systematic procedure, their stated meetings, and their friendly discussions, answer this demand, and that the temporary boards, however valuable they may be in a given case, do not. These permanent voluntary boards, recognizing the perfect equality of employer and employed, and the right of each to an equal voice in the settlement of all questions, meeting at stated times, when no demand has been formulated, no positions assumed, no bitterness engendered, afford opportunities for the rapid growth of that mutual confidence which must exist if any method of harmonizing differences be effective. The great hindrance to the settlement of these questions is the unnecessary antagonistic positions of employer and employed. If these can be got to shake hands in a friendly manner, to learn to have confidence in each other, to sit down at a table as equals and talk their differences over as they arise, and before they grow into disputes, the first step for a better understanding and for a settlement of these differences is taken.

Without considering here the general question of arbitration and conciliation as against other methods of settling labor disputes, but the only, the best forms of these boards, it seem clear that the permanent boards of arbitration and conciliation are to be preferred to any temporary boards, and to boards of conciliation alone.

In their origin and methods arbitration and conciliation are either —

First. *Legal;* that is, established and operated under statute

law, with its sanctions and also its powers for enforcing awards or agreements; or,

Second. *Voluntary;* that is, established and operated by mutual agreement, the honor of the parties being the only surety for the acceptance of the awards or agreements.

The best, and indeed the only eminently successful, example of legal arbitration and conciliation is to be found in the *Conseils des prudhommes*, which have existed in France and Belgium since early in the present century. These are tribunals established by law at the great industrial centers for the purpose of settling labor differences. The submission of questions may be either voluntary or compulsory. The councils are invested with judicial power, but this power is not used until an attempt to reach an agreement has failed. Then the party declining conciliation is compelled to accept arbitration, and the award can be enforced the same as that of any other court of law.

The authority of these councils extends to every conceivable question that can arise in the workshop, not only between the workman and his employer, but between the workman and his apprentice or the foreman. There is but one question they cannot, upon the application of either party, consider,—future rates of wages; but even this can be done by mutual agreement.

Legal arbitration and conciliation have practically no existence either in England or the United States. In England the parties to labor differences persistently decline to avail themselves of the provisions of the several arbitration acts, while the quasi-legal boards in this country are legal in name rather than in fact. Whatever of success has been attained in these two countries in applying this principle to labor differences has been chiefly through voluntary boards or committees, the two great English-speaking nations presenting in this respect a contrast to the two French States, France and Belgium, in which legal arbitration and conciliation prevail.

A moment's consideration of the causes of the differences which arbitration and conciliation seek to remove, and a clear recognition of the real authority in which power concerning these differences is lodged, and to which ultimately an appeal must lie, is convincing that this voluntary form is the only one that gives promise of success in dealing with those questions that most frequently lead to industrial warfare.

As has been pointed out, labor differences arise concerning both past and future contracts, and also grow out of "matters of sentiment." From their very nature it is evident that it is only a very limited range of difficulties, chiefly those involving the terms and construction of contracts under which work has already been done, that legal or compulsory arbitration and conciliation, relying as it does upon the State to give effect to its decisions, can deal with any degree of efficiency. It is natural and proper that the parties to such differences, involving as they do work done and money earned,— that is, actual property,— should be compelled, if necessary, to submit their differences to a competent tribunal, and when that tribunal has honestly and carefully reached a decision, that the State by all its agencies should give it effect. In dealing with such questions these boards or committees are but courts of law unfettered by their forms or ceremonies.

But it is not concerning past contracts or work done that differences and disputes most frequently arise, but as regards the future, and here legal arbitration and conciliation is confessedly powerless. Every law providing for legal arbitration formally recognizes its limitations, and provides that the boards or *conseils* organized under them shall not deal with future rates of wages unless by mutual consent. Even then the awards cannot be enforced unless this consent is renewed after the finding. There is no power in the State to compel the performance of work under the terms of an award without recourse to practical confiscation and absolute slavery. Law cannot force men to work at rates nor upon terms to which they will not agree, nor can it compel an employer to operate his works and furnish employment. In a word, there is no power outside the parties themselves that can give effect to a decision as to a future contract or that can harmonize quarrels over matters of sentiment. It is with them that power is lodged, and to them appeal must ultimately lie. Within the realm of labor to a degree unknown elsewhere government exists only by the consent of the governed.

It is in the complete recognition of this fact at all stages of its proceedings, the submission, discussion, award, and enforcement that is the strength and justification of the system of voluntary arbitration and conciliation. It is because it furnishes a method, and the only one, for securing that consent without which no method of harmoniz-

ing the relations and settling or preventing the differences between employer and employed can be of any value that it must ultimately prevail. It is the government of reason, finding its sanctions in the freely-given consent, their loyalty to themselves, of the subjects of its reign.

I will not take your time by giving examples of the successful practice of arbitration, nor the details of the organization or methods of these boards. For these I refer you to my reports made to the governor of Pennsylvania in 1878, and to the Massachusetts Bureau of Labor Statistics in 1880.

Before closing, however, let me answer one or two objections to the system.

Probably the most strongly-urged objection to arbitration and conciliation is that it seeks to settle the terms upon which work shall be done in the future. These, it is held, cannot, in the very nature of things, be subjects of agreement or award, as they depend on the course of future events, which is unknown. A decision, therefore, may not only be erroneous and injurious, but it may also interfere with what the economists of a certain school call iudustrial freedom, by which is meant an impulse to seek surely and swiftly the best markets.

So far as this objection is based on the assumed authority and sufficiency of competition, it has already been discussed. There is apparent force, however, in that part of it which asserts the liability to error arising from want of knowledge of the future. The elements necessary to accurate determination are wanting, and it is possible that the judgment of the board or umpire may be at fault, and errors may occur, but are errors more likely to happen in a system which brings reason and deliberation to the estimation of probabilities than in one that takes passion or greed as its prophet? For it is to be remembered that these questions as to the future must be answered. They are ever present. They will not down. They cannot be ignored. They must be met, and whatever view may be taken of their legitimacy, they must be answered. Labor demands to know the terms upon which it is to toil before it will work. An answer to its demand being imperative, is there any method that has yet been suggested that promises to answer as justly or correctly as arbitration?

But it is by no means clear that the future is not a proper subject of agreement or award. There are many questions relating to methods of work and administration that most certainly are. Endless confusion and innumerable conflicts would result were not these details subjects of agreement beforehand. Further, the fixing of future rates of wages is not only not theoretically unsound, but it is in accordance with the most obvious business practice and prudence. It is absolutely impossible in the present organization of industry that work should go on one moment without an agreement as to what wages shall be. This is too obvious to need discussion, and whether that agreement is for a year or for a day, it is fixing future rates of wages. There may be a question as to the proper duration of the agreement,— that is, how long the rates shall obtain,— but there can be no question as to the necessity of some agreement. Further, such fixing of future wages is exactly analogous to the very common and commendable practice of buying and selling goods for future delivery. Its advantages, in view of modern commercial methods, are beyond question. A rate of wages established for a fixed period justifies an employer in entering upon contracts for the purchase of materials and the delivery of goods with a certainty that cannot exist when these rates may be advanced tomorrow. As has been stated, the length of time an agreed rate of wages shall be in force is a subject for agreement the same as the rate itself, but even here the difficulties and injuries arising from frequent adjustments may be largely overcome by the adoption of sliding scales; indeed, these sliding scales remove many of the objections to fixing future rates of wages. Once agreed upon, under their operation, wages conform themselves to selling price, to the course of events, without confusion, without friction. It may also be said in passing that they are a practical recognition of the true theory of wages.

Another objection to arbitration is that the awards and decisions are usually compromises. By this is meant that neither party to the submission gets what it asks, or there is what is termed "splitting the difference." Even if this were true, it would not be surprising. It requires but little experience with labor differences to learn that it is by no means uncommon for both sides to demand more than they expect to get for the very purpose of having something to concede. This "higgling of the market" is as old as buying and selling. "*In*

medio tutissimus ibis" is very often a safe rule in settling labor differences. But while this is true in very many cases, and as true where arbitration is not appealed to as when it is, I assert that the records of arbitration disprove the assertion that its results are usually "compromises." Even where an award between the demands of the parties is made, in but a few instances is it "splitting the difference." The awards are, with rare exceptions, honest decisions, based upon the facts and arguments presented. If it happens that they do "split the difference" that is not chargeable to arbitration.

Another objection to arbitration is that the awards are not accepted by one or both parties, or, as it is usually expressed, "are not lived up to." It is true that in some cases, much less frequently than is generally believed, the awards of umpires or the decisions of boards have been rejected after the parties have bound themselves by the most sacred of obligations, their honor, to abide by the result. But is there any method of settling labor differences of which the same cannot be said? Is the result of a strike or lock-out any better "lived up to"? Would the parties who thus violate their pledged word of honor accept any decision, however reached, that did not accord with their views, or, in other words, did not make them the judge and arbitrator? The objection lies not against the system. It is against the individuals it deals with.

But, granting that there are some instances of rejection of awards, is it not equally true that this is the only system that provides for and secures the settlement of these questions for a definite time? When an agreement is reached or an award made and accepted, there is little doubt as to its being loyally observed. The wages of certain classes of skilled labor in the iron mills of Pittsburg have been regulated since 1865 by what are termed "conference committees," which are really temporary committees of conciliation. In these twenty-one years there is not a single instance of the violation of an agreement once reached. Even when, as in one case, there has been such a change in values as to lead the manufacturers to suggest a change in the agreement favorable to the workmen, it was rejected by the employés on the ground that they would not consent to the least violation or change in the agreement, even in their own favor.

A more serious objection to arbitration in the minds of many is that it seems to necessitate the existence and recognition of trades

unions and employers' associations, both to provide for the election of members of the board and to furnish that power that shall compel the acceptance of the awards.

It is not necessary, though it will usually be found advisable, to have the members of the board representing labor elected by labor in some organized form. There is, then, a tangible body responsible for the selection. To it appeal can be had, and by it discipline can be administered. An unorganized crowd is usually neither as deliberate, as wise, nor as conservative in its actions as one that has put itself under the restraint of laws, precedents, and officers.

But it is conceded that at present there seems to be no other authority possessed of the power, which at times is necessary to enforce obedience to awards, than that residing in unions. As has been pointed out, in all settlements of labor differences, by whatever method, the measure of success is the consent of the parties. Experience has shown that that consent is capricious, and the honor and pledged word of the parties at times of little value. This is as true in settlements reached without arbitration as of those the results of this method. The necessity of a power strong enough to compel the acceptance of settlements, and so constituted that it can enforce its commands, is evident. The State, as the embodiment of law and power, has been suggested, but in these matters it is powerless. It is evident that as the measure of power is the consent of the governed, the power to enforce the awards must come from the parties themselves,— that is, unions. It will be found that the success of arbitration has been secured where there have been strong unions to compel the acceptance of the awards.

It is not my purpose to discuss the advisability of unionism. From what has already been said, it will be inferred that to the principle I give my hearty assent. I believe with the Duke of Argyle, "that combinations of workingmen for the protection of their labor are recommended alike by reason and experience." What I desire to ask those who object to arbitration on this account is, if their objection will do away with unionism, or if it will remove the necessity of recognizing and treating with unions in the near future. Unionism is here, and it will not depart. It is growing yearly in power, in wisdom, and in organization. It cannot be crushed out; it will not permit itself always to be ignored or despised. Is it wisest

to treat it as an enemy or a friend? Is it not best to make it, in the language of the Count of Paris, "a new element of productive power and an earnest pledge of peace"?

The most effective pledge of industrial peace, in view of the present constitution of industrial society, and the conditions which obtain, is arbitration and conciliation, with strong unions to enforce its decisions. I speak of strong unions, for it is only a strong union that dare be just. A weak union, which represents but a part of a section or trade, is timid and cowardly, and yet tyrannical, and seeks to make up in bluster and flagrant injustice what it lacks in power. But a strong union can be just and generous without fear of being charged with cowardice, and when there is beside it a strong employers' association, strikes and lock-outs will be of rare occurrence, peace will be assured, and production go forward under the most promising conditions.

The thanks of the Society were passed to the speaker for his very interesting and instructive paper.

MEETING 347.

The Chemistry of Foods and Nutrition.

BY PROF. W. O. ATWATER.

The 347th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 22nd, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, and the transaction of some business, the president introduced Prof. W. O. Atwater, of Wesleyan University, who read a paper on "The Chemistry of Foods and Nutrition."

Prof. ATWATER said: This subject has of late occupied a great deal of attention among chemists and physiologists. During the last two or three decades particularly a very large amount of research has

been devoted to it, especially in Germany, though comparatively little has as yet been done in this line in the United States.

Viewed from the standpoint of their uses in the nutrition of man, the constituents of ordinary food-materials may be divided into (1.) *Edible substance*, e.g., the flesh of meats and fish, the shell-contents of oysters, or wheat-flour; (2.) *Refuse*, e.g., bones of meat and fish, bran of wheat. The edible substance consists of water and nutritive ingredients or nutrients. In studying the uses of food in nutrition, the nutrients only demand special consideration. Speaking as chemists and physiologists, we may say then that our food supplies, besides water, four principal classes of nutritive ingredients or nutrients, viz., protein, carbohydrates, fats and mineral matters; and that these nutrients are transformed into the tissues and fluids of the body, and are consumed to produce heat and muscular and intellectual energy.

In studying foods we may consider their chemical composition, their digestibility, their pecuniary cost as compared with their composition, the physiological economy of their use, including the functions of the ingredients, their potential energy, the quantities appropriate for the nutrition of different people, and the adjustment of dietaries to the wants of the users; and, finally, the injury to health and purse which comes from the wrong use of food, and the ways in which our dietary habits may be improved.

The term protein is applied to a variety of compounds, all of which contain nitrogen. The most important are, (1), the albuminoids, or proteids; such as the albumen of eggs, myosin of muscle (lean of meat); casein of milk and gluten of wheat; (2), gelatinoids, e.g., ossein of bone and the collagen of tendons, which, when boiled, yield gelatin. The principal carbohydrates are starch, sugar, and cellulose (woody fiber). We have examples of fats in the fat of meats, butter, olive oil, oil of corn, and wheat; among the mineral matters, the phosphates and chlorides of calcium, potassium, etc. The quantities of water, nutrients, etc., contained in different food-materials were illustrated in detail by colored diagrams, and are here shown in Tables I., II., and III.

TABLE I.

Composition of Animal Foods. Edible Portion — Flesh, etc., Freed from Bone, Shells, and other Refuse.

[Italics indicate European analyses, the rest are American.]

KINDS OF FOOD-MATERIALS.	Water.	Nutrients.	NUTRIENTS. Protein (albuminoids).	Fats.	Carbohydrates.	Salt.	Ash.
MEATS — Fresh.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.		Per ct.
Beef, side, well fattened, . . .	54.7	45.3	17.2	27.1	–		1.0
Beef, lean, nearly free from fat,	76.0	24.0	21.8	0.9	–		1.3
Beef, round, rather lean, . . .	66.7	33.3	23.0	9.0	–		1.3
Beef, sirloin, rather fat, ...	60.0	40.0	20.0	19.0	–		1.0
Beef, neck, ...	62.0	38.0	19.2	17.8	–		1.0
Beef, liver, ...	69.5	30.5	20.1	5.4	3.5		1.5
Beef, tongue, ...	63.5	36.5	17.4	18.0	–		1.1
Beef, heart, ...	56.5	43.5	16.3	26.2	–		1.0
Veal, lean, ...	78.8	21.2	19.7	0.8	–		0.7
Veal, rather fat, ...	72.3	27.7	18.9	7.5	–		1.3
Mutton, side, well fattened, . .	45.9	54.1	14.7	38.7	–		0.7
Mutton, leg, ...	61.8	38.2	18.3	19.0	–		0.9
Mutton, shoulder, ...	58.6	41.4	18.1	22.4	–		0.9
Mutton, loin (chops), ...	49.3	50.7	15.0	35.0	–		0.7
MEATS — Prepared.							
Dried beef, ...	58.6	41.4	30.3	4.4	–		6.7
Corned beef, rather lean, . . .	58.1	41.9	13.3	26.6	–		2.0
Smoked ham, ...	41.5	58.5	16.7	39.1	–		2.7
Pork, bacon, salted, ...	10.0	90.0	3.0	80.5	–		6.5
FOWL.							
Chicken, rather lean, ...	72.2	27.8	24.4	2.0	–		1.4
Turkey, medium fatness, . . .	66.2	33.8	23.8	8.7	–		1.3
Goose, fat, ...	38.0	62.0	15.9	45.6	–		0.5
DAIRY PRODUCTS, EGGS, ETC.							
Cow's milk, ...	87.4	12.6	3.4	3.7	4.8		0.7
Cow's milk, skimmed, ...	90.7	9.3	3.1	0.7	4.8		0.7
Cow's milk, buttermilk, ...	90.3	9.7	4.1	0.9	4.0		0.7
Cow's milk, whey, ...	93.2	6.8	0.9	0.2	5.0		0.7
Cheese, whole milk, ...	31.2	68.8	27.1	35.5	2.3		3.9
Cheese, skimmed milk, ...	41.3	58.7	38.4	6.8	8.9		4.6
Butter, ...	9.0	91.0	1.0	87.5	0.5		2.0
Hen's eggs, ...	73.1	26.9	13.4	11.8	0.7		1.0
FISH, ETC.							
Flounder, ...	84.2	15.8	13.8	0.7	–		1.3
Haddock, ...	81.4	18.6	17.1	0.3	–		1.2
Bluefish, ...	78.5	21.5	19.0	1.2	–		1.3
Cod, ...	82.6	17.4	15.8	0.4	–		1.2
Whitefish, ...	69.8	30.2	22.1	6.5	–		1.6
Shad, ...	70.6	29.4	18.5	9.5	–		1.4
Mackerel, average, ...	71.6	28.4	18.8	8.2	–		1.4
Salmon, ...	63.6	36.4	21.6	13.4	–		1.4
Salt cod, ...	53.8	26.1	21.7	0.3	–	20.1	4.1
Smoked herring, ...	34.5	53.8	36.4	15.8	–	11.7	1.6
Salt mackerel, ...	42.2	47.2	22.1	22.6	–	10.6	2.5
Oysters, ...	87.2	12.8	6.0	1.2	3.6		2.0
Scallops, ...	80.3	19.7	14.7	0.2	3.4		1.4

TABLE II.

Composition of Animal Foods. Specimens as Purchased in the Markets (including both Edible Portion and Refuse).

[Italics indicate European analyses, the rest are American.]

KINDS OF FOOD MATERIALS.	Refuse: bones, skins, shells, etc.	EDIBLE PORTION.					
		Water.	Nutrients.	NUTRIENTS.			
				Protein (albuminoids).	Fats.	Carbo-hydrates, etc.	Mineral matters.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
MEATS — Fresh.							
Beef, side, well fattened, .	19.7	44.0	36.3	13.8	21.7	..	0.8
Beef, round, rather lean, .	10.0	60.0	30.0	20.7	8.1	..	1.2
Beef, sirloin, rather fat, . .	25.0	45.0	30.0	15.0	14.3	..	0.7
Beef, neck, ...	19.9	49.6	30.5	15.4	14.3	..	0.8
Beef, tongue, ...	15.3	54.0	30.7	14.5	15.4	..	0.8
Beef, heart, ...	6.0	53.4	40.6	14.8	24.8	..	1.0
Mutton, side, well fattened,	20.0	42.9	37.1	13.2	23.2	..	0.7
Mutton, leg, ...	18.4	50.4	31.2	15.0	15.5	..	0.7
Mutton, shoulder, ...	16.8	48.7	34.5	15.0	18.7	..	0.8
Mutton, loin (chops), . . .	16.3	41.3	42.4	12.5	29.3	..	0.6
MEATS — Prepared.							
Dried beef, ...	6.5	55.5	38.0	27.4	4.2	..	0.4
Corned beef, rather lean, .	6.2	54.5	39.3	12.5	24.9	..	1.9
Smoked ham, ...	12.5	36.3	51.2	14.6	34.2	..	2.4
Pork, bacon, salt, ...	5.0	9.5	85.5	2.8	76.5	..	6.2
FOWL.							
Chicken, rather lean, . . .	41.6	42.2	16.2	14.2	1.2	..	0.8
Turkey, medium fatness, .	35.4	42.8	21.8	15.4	5.6	..	0.8
DAIRY PRODUCTS, EGGS, ETC.							
Cow's milk, ...	..	87.4	12.6	3.4	3.7	4.8	0.7
Cow's milk, skimmed, ...	..	90.7	9.3	3.1	0.7	4.8	0.7
Cow's milk, buttermilk, . .	..	90.3	9.7	4.1	0.9	4.0	0.7
Cow's milk, whey, ...	..	93.2	6.8	0.9	0.2	5.0	0.7
Cheese, whole milk, ...	..	31.2	68.8	27.1	35.5	2.3	3.9
Cheese, skimmed milk, . .	..	41.3	58.7	38.4	6.8	8.9	4.6
Butter, ...	..	9.0	91.0	1.0	87.5	0.5	2.0
Hen's eggs, ...	13.7	63.1	23.2	11.6	10.2	0.6	0.8
FISH, ETC.							
Flounder, whole, ...	66.8	27.2	6.0	5.2	0.3	..	0.5
Haddock, dressed, ...	51.0	40.0	9.0	8.2	0.2	..	0.6
Bluefish, dressed, ...	48.6	40.3	11.1	9.8	0.6	..	0.7
Cod, dressed, ...	30.0	58.4	11.6	10.6	0.2	..	0.8
Whitefish, whole, ...	53.5	32.5	14.0	10.3	3.0	..	0.7
Shad, whole, ...	50.1	35.2	14.7	9.2	4.8	..	0.7
Mackerel, average whole, .	44.6	40.4	15.0	10.0	4.3	..	0.7
Salmon, whole, ...	35.3	40.6	24.1	14.3	8.8	..	1.0
							Salt.
Salt cod, ...	24.9	40.3	19.4	16.0	0.4	..	15.4 3.0
Smoked herring, ...	44.4	19.2	29.9	20.2	8.8	..	6.5 0.9
Salt mackerel, ...	33.3	28.1	31.5	14.7	15.1	..	7.1 1.7
Oysters, in shell, ...	82.3	15.4	2.3	1.1	0.2	0.6	0.4
Oysters, solid, ...	..	87.2	12.8	6.3	1.6	4.0	0.9
Scallops, edible portion, . .	..	80.3	19.7	14.7	0.2	3.4	1.4

TABLE III.

Constituents of Vegetable Foods and Beverages.

[The analyses of foods in Roman letters are American, those of foods and beverages in italics are European.]

KINDS OF FOOD AND BEVERAGES.	Water.	NUTRIENTS. Protean (albuminoids).	Fats.	Carbohydrates, etc.	Woody fiber.	Mineral matters.
FOODS.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Wheat flour, average,*	11.6	11.1	1.1	75.4	0.2	0.6
Wheat flour, maximum,* . . .	13.5	13.5	2.0	78.5	1.2	1.5
Wheat flour, minimum,* . . .	8.3	8.6	0.6	68.3	0.1	0.3
Graham flour (wheat), ...	13.0	11.7	1.7	69.9	1.9	1.8
Cracked wheat, ...	10.4	11.9	1.7	74.6		1.4
Rye flour, ...	13.1	6.7	0.8	78 3	0.4	0.7
Pearled barley, ...	11.8	8.4	0.7	77.8	0.3	1.0
Buckwheat flour, ...	13.5	6.5	1.3	77.3	0.3	1.1
Buckwheat "farina,"	11.2	3.3	0.3	84.7	0.1	0.4
Buckwheat "groats,"	10.6	4.8	0.6	83.1	0.3	0.6
Oatmeal, ...	7.7	15.1	7.1	67.2	0.9	2.0
Maize meal, ...	14.5	9.1	3.8	69.2	1.8	1.6
Hominy, ...	13.5	8.3	0.4	77.1	0.3	0 4
Rice, ...	12.4	7.4	0.4	79.2	0 2	0.4
Beans, ...	13.7	23.2	2.1	53.7	3.7	3.6
Pease, ...	15.0	22.9	1.8	52.4	5.4	2.5
Potatoes, ...	75.5	2.0	0.2	20.5	0.8	1.0
Sweet potatoes, ...	75.8	1.5	0.4	20.0	1.1	1 2
Pole beans, ...	83.5	2.8	0.3	10.0	2.6	0.8
Green pease, ...	81.8	3.4	0.4	12.1	1.6	0.7
Turnips, ...	91.2	1.0	0 2	6.0	0.9	0.7
Beets, ...	83.9	2.1	0.1	11.7	1.2	1.0
Carrots, ...	87.9	1.0	0.2	8.9	1.2	0.8
Onions, ...	89.3	1.1	0.2	8.3	0.6	0.5
Cabbage, ...	90.0	1.9	0.2	4.9	1.8	1.2
Lettuce, ...	94.3	1.4	0.3	2.2	0.7	1.1
Cauliflower, ...	90 4	2.5	0.4	5.0	0.9	0.8
Tomatoes, ...	92.4	1.3	0.3	4.6	0.8	0.6
Melons, ...	95.2	1.1	0.6	1.4	1.1	0.6
Pumpkins, ...	90.0	0.7	0.1	7.3	1.3	0.6
Squash, ...	87.8	0.7	0.2	9.1	1.1	1.1
Apples, ...	84.8	0.4	..	12.8	1.5	0.5
Pears, ...	83.0	0.4	..	12.0	4.3	0.3
Starch, ...	15.1	1.2	..	83.3	..	0.4
Tapioca, ...	13.3	0.6	86.0		..	0.1
Cane-sugar, ...	2.2	0.3	..	96.7	..	0.8
Molasses, ...	24.6	..	..	71.0	‡	2.3
Wheat bread,†	32.7	8.9	1.9	55.5		1.0
Graham bread, ...	34.2	9.5	1.4	53.3		1.6
Rye bread, ...	30.0	8.4	0 5	59.7		1.4
Soda crackers, ...	8.0	10 3	9.4	70.5		1.8
"Boston" crackers, ...	8.3	10.7	9.9	68.7		2.4
"Oyster" crackers, ...	3.9	12.3	4.8	76.5		2.5
Oatmeal crackers, ...	4.9	10.4	13.7	69.6		1.4
Pilot (bread) crackers, ...	7.9	12.4	4.4	74.2		1.1
Macaroni, ...	13.1	9.0	0.3	76.8		0.8
BEVERAGES.			Alcohol		Free acid.	
Lager beer, ...	90.3	0.5	4.0	5.0	..	0.2
Porter and ale, ...	88.5	0.7	5.2	5.3	..	0.3
Rhenish wine, white, ...	86.3	..	10.5	2.6	0.4	0.2
Rhenish wine, red, ...	86.9	..	8.9	3.4	0.5	0.3
French wine, claret, ...	88.4	..	8 1	2.7	0.6	0.2

* Of analyses of American flours. The figures for "maximum" and "minimum" denote the largest and smallest percentages, respectively, found in the analyses. The sum of the figures representing the maximum must, therefore, exceed, and those for minimum fall below, 100 per cent.

† *From flour of about average composition.*

‡ Other organic matter, 2.1.

Thus in lean beef, such as round steak as we buy it in the markets, there is about ten per cent of refuse in the form of bone, sixty per cent of water, and thirty per cent of nutrients, of which latter the protein makes up twenty-one per cent, the fats eight per cent, and the mineral matter one per cent. The quantity of refuse in our ordinary meats varies from five to twenty-five per cent, or thereabouts, the water from ten per cent in fat pork to sixty per cent in lean beef, and the total nutrients from eighty-five per cent in fat pork to thirty per cent or forty per cent in ordinary beef and mutton. The protein, which is the most valuable of the nutrients, ranges from twelve to twenty per cent in beef and mutton, and from two to twelve per cent in pork. The most marked difference among the meats is in the quantities of fat, which may be as low as eight per cent or lower in lean beef and veal, or as high as twenty-five per cent in fat beef and mutton, and may reach seventy-five per cent in fat pork. Fish, as we buy them, contain more refuse and water and less nutritive material than the meats, the quantities of nutrients varying from six per cent in fresh flounder and twelve per cent in fresh cod, to twenty per cent in salt cod and thirty-two per cent in salt mackerel. The nutrients of fish consist mostly of protein. When, however, we consider the edible portion of meats and fish after the bone and other refuse has been removed, there are, of course, proportionally larger quantities of nutrients. Ordinary cow's milk contains about twelve and a half per cent of nutrients and eighty-seven and a half per cent of water. While the nutrients in milk are thus about one-eighth of the whole, those of cheese make about two-thirds, and those of butter nine-tenths of the whole weight. Oleomargarine has about the same composition and nutritive value as butter. Oysters, like milk, contain about one-eighth nutrients and seven-eighths water. The oysters have rather more protein than the milk, while the milk has more of fats than the oysters. The vegetable foods have, in general, less water and more nutrients than the animal foods, but potatoes, turnips, and the succulent vegetable food materials generally have large quantities of water. Thus the potato has about three-quarters water and one-quarter nutritive material. But a most important difference between the vegetable and the animal foods is found in the fact that the vegetables in general contain large quantities of carbohydrates, of which the animal foods contain little or none. Wheat flour has on

the average about twelve per cent of water, eleven per cent of protein, one per cent of fats, and seventy-five per cent of carbohydrates. Bread differs from flour mainly in having more water. Thus ordinary loaves of bread will contain from thirty-three to thirty-eight per cent of water, so that one hundred pounds of bread would have less nutritive material than one hundred pounds of flour by the amount of water which the bread contains in excess of the flour. Corn meal has a little less protein and more fat than wheat flour; beans and peas are much richer in protein than wheat. Oat meal stands between wheat flour and beans.

The question of the digestibility of foods is a very complex and difficult one, and it is to be noticed that the men who know most about it are generally the least ready to make definite and sweeping statements as to the digestibility of this or that kind of food material. One great difficulty is the fact that what we ordinarily call the digestibility of a food includes several different things,— the ease with which it is digested, the time required for digesting it, and the proportions of its several constituents that are digested.

The ease of digestion of a given food material, and its suitableness to the digestive organs of a given person, are physiological questions, hardly capable of a categorical answer. The actual amounts digested are capable of more nearly accurate determination.

This is done by direct experiments in which the quantities of food and of undigested material are compared. Such experiments upon human subjects are rather difficult, since it is not easy for ordinary persons to continue to eat the same kind of food long enough for a satisfactory experiment. A considerable number of experiments have, however, been made. The general results are that the protein of the animal foods is more completely digested than that of vegetable foods, while the carbohydrates which occur chiefly in the vegetable foods are digested as completely as the protein of the animal foods. Thus in meats, fish, and eggs from ninety-eight to ninety-nine per cent of protein is found to be digested by healthy men. The same persons digest from eighty-nine to ninety-four per cent of the protein of milk, from seventy-five to eighty-two per cent of the protein of wheat bread, corn meal, peas, etc., while from potatoes and beets only from sixty to seventy per cent of protein is digested. Bread made from whole wheat flour is not digested as completely as that from ordinary

flour. There is, therefore, no special economy in leaving the bran in the wheat in grinding, though the therapeutic effect of the bran is sometimes beneficial. Of the carbohydrates of vegetable foods from eighty to ninety per cent are digested. Those of coarse bread, potatoes, and beets are the least, and those of ordinary flour and meal the most, completely digested. The fats of various food materials are variable in digestibility.

The comparative costs of actual nutrients of foods are found by comparing the composition with the price. One method consists in comparing the costs of a given class of nutrients, as, for instance, protein in the different food materials. Table IV. gives the results of these computations.

TABLE IV.

Comparative Expensiveness of Actual Nutrients of Foods.—Costs of a Pound of Protein in Different Food Materials at Ordinary Prices.

(Allowance being made for the other nutrients in each case.)

FOOD MATERIALS.	Prices.		Costs of Protein. Cents.
Beef, sirloin,	25	cents per pound.	106
Beef, "	20	" "	86
Beef, round,	18	" "	70
Beef, neck,	8	" "	33
Beef, tenderloin,	60	" "	235
Mutton, leg,	22	" "	91
Pork, salted, fat,*	12	" "	25
Salmon,	30	" "	153
Shad,	12	" "	99
Cod,	8	" "	75
Canned salmon,	20	" "	70
Salt cod,	5	" "	31
Oysters,	50	" per quart.	336
Milk,	8	" "	61
Cheese, whole milk,	15	" per pound.	31
Cheese, skimmed milk,	8	" "	18
Wheat flour,	4	" "	15
Wheat "	3	" "	12
Wheat bread,	6	" "	29
Indian meal,	3	" "	12
Indian "	2	" "	8
Oat meal,	5	" "	15
Beans	10	" per quart.	14
Potatoes,*	100	" per bushel.	30
"	50	" "	15

* Contain very little protein.

Thus it appears that the nutrients of vegetable foods are in general much less costly than in animal foods, but the animal foods have, as above stated, the advantage of containing a larger proportion of protein and fats, and the protein, at least, in more digestible forms. Among the animal foods those which rank as delicacies are the costliest. The protein in the oysters and tenderloin of beef at ordinary prices costs from two to three or four dollars per pound. In salmon in early spring, when the price is a dollar a pound, the cost of a pound of protein rises to over five dollars. In the common kinds of beef, mutton, and ham it varies from one hundred and six to thirty-three cents; in shad, bluefish, haddock, and halibut the range is about the same, while in cod and mackerel, fresh and salted, it varies from seventy-five to as low as thirty-one cents per pound. Salt cod and salt mackerel are nearly always, fresh cod and mackerel often, and even the choicer fish, as bluefish and shad, when abundant, cheaper sources of protein than any but the cheapest kinds of meat. The peculiar taste of people in Boston, which calls for the choicer parts of beef, and refuses the so-called coarser portions, as the shoulder, neck, fore-ribs, etc., which are just as nutritious as any, causes these latter portions of the beef to be sold at prices which bring the nutrients down to extremely low figures, a matter which, if understood, can be taken advantage of by people who desire to economize. Among meats, pork is the cheapest; but salt pork or bacon has the disadvantage of containing very little protein. Skimmed-milk cheese at eight cents per pound furnishes protein at only eighteen cents per pound. The protein in vegetable foods is much less costly. In wheat bread at six cents per pound, and in potatoes at one dollar per bushel, a pound of protein costs about thirty cents. In flour at four cents, and in oat meal at five cents per pound, and in potatoes at fifty cents per bushel, it comes to fifteen cents, while in Indian meal at two cents per pound, a pound costs only eight cents. Another, and, in fact, more satisfactory method of estimating the relative cheapness of different food materials is by calculating, from comparison of composition and cost, the quantities of nutrients obtained for twenty-five cents, as is shown in table V.

TABLE V.

Quantities of Nutrients Obtained for 25 Cents in Different Food Materials when Purchased at Ordinary Prices.

	At prices per pound. Cents.	Food materials obtained. Pounds.	Nutrients in Food Materials. Protein. Pounds.	Fats. Pounds.	Carbo-hydrates. Pounds.	Potential Energy. Foot-tons.
Beef, sirloin, medium fatness,	25	1.00	.15	.14	–	6042
Beef, " " "	20	1.25	.19	.18	–	7730
Beef, round, ...	18	1.39	.29	.11	–	6971
Beef, neck, ...	8	3.13	.48	.44	–	19098
Beef, tenderloin, ...	60	.42	.09	.03	–	2737
Mutton, leg, ...	22	1.14	.17	.17	–	7171
Pork, salted, fat, ...	12	2.08	.06	1.59	–	47367
Salmon, ...	30	.83	.12	.07	–	3602
Shad, ...	12	2.08	.19	.10	–	5386
Cod, ...	8	3.13	.33	.01	–	4557
Canned salmon, ...	20	1.25	.25	.19	–	8798
Salt cod, ...	5	5.00	.80	.02	–	10924
Oysters, 50 cents per quart, .	25	1.00	.06	.02	.04	1878
Milk, 8 cents per quart, . . .	4	6.25	.21	.23	.30	13330
Cheese, whole milk, ...	15	1.67	.45	.59	.04	23620
Cheese, skimmed milk, . . .	8	3.13	1.20	.21	.28	25278
Butter, ...	30	.83	–	.73	–	21391
Wheat flour, ...	4	6.25	.69	.04	4.71	70950
Wheat "	3	8.33	.92	.09	6.28	95674
Wheat bread, ...	6	4.17	.37	.07	2.31	36682
Indian meal, ...	3	8.33	.70	.29	5.91	93911
Indian "	2	12.50	1.05	.44	8.87	141077
Oat meal, ...	5	5.00	.76	.36	3.36	63787
Beans, 10 cents per quart, . .	5	5.00	1.16	.11	2.69	52972
Potatoes, $1.00 per bushel, . .	1.7	13.24	.27	.03	2.74	39773
Potatoes, 50 cents per bushel,	0.85	26.47	.53	.05	5.48	79125
Daily dietary for laboring men at moderate work, ...	–	–	.26	.12	1.10	21221

It is worth the noting that oat meal is one of the cheapest foods that we have; that is, it furnishes more nutritive material, in proportion to the cost, than almost any other food. Corn meal is, indeed, cheaper, but the oat meal has this great advantage over corn meal and wheat flour, that it has more protein. Of course, if we are to eat large quantities of lean meat,—and many people, doubtless, eat more than is best for their health, saying nothing of their purses,—the

extra protein in the oat meal is of little consequence to us. But if one wishes to economize in his food, oat meal, rightly cooked, affords an excellent material therefor.

One of the most interesting things brought out in the table is the cheapness of the staple vegetable food materials,— such as potatoes, wheat flour, corn meal, oat meal, and beans.

Of no less practical and much more scientific interest are the ways in which food is used in the body. Our best knowledge of these subjects comes from experiments in which the income and expenditure of the body are determined. The most elaborate, and at the same time most interesting, experiments of this class are those with the respiration apparatus, in which the food and all of the products of its use in the body, solid, liquid, and gaseous, are determined. The apparatus and method of experimenting were described. Thus, in one experiment, a man was put inside the apparatus, and kept without food for twenty-four hours, and it was found that his body consumed a little over two ounces of its protein, and a half pound of its fat for its support. When the same man was kept in the apparatus, and received a liberal allowance of food without doing any work, he was found in one case to gain about two ounces of fat in a day, but when during another twenty-four hours he received the same food, but worked hard at the lathe for ten hours or so, his body lost two ounces of fat.

By thus striking a balance between income and outgo with food of varying composition, the part played by each class of nutrients in the nourishment of the body is determined.

It appears that the protein forms the (nitrogenous) basis of the blood, and builds up the muscle and other tissues, that it is transformed into fat, and that it serves for fuel to produce heat for keeping the body warm, and muscular energy for its work. The fat of food is stored as fat in the body, and also serves for fuel. Both protein and fats are doubtless transformed into carbohydrates in the body.

The carbohydrates are transformed into fat, and serve for fuel. In order to be adequately nourished, we must have a certain amount of protein to build up the tissues. This is indispensable since none of the other ingredients can do this work of the protein in the formation of nitrogenous tissue. We also need a certain amount of mate-

rial for fuel. For this purpose either protein, fats, or carbohydrates may do, to greater or less extent, but the most healthful diet is one that contains all these ingredients in proper portions.

Another matter of interest is found in the quantities of potential energy contained in our foods. When coal is burned under the steam boiler, heat is developed by the union of its carbon with oxygen. When the water changes to steam in the boiler, this heat is transformed into mechanical energy with which the engine does its work. In like manner the nutrients of our foods are consumed in the body, and yield heat and muscular energy. The amount of mechanical energy which would raise one ton to the hight of one foot is called a foot-ton.

TABLE VI.

Potential Energy in Nutrients of Common Food Materials.—Mechanical Equivalents Expressed in Foot-Tons of Energy in One Pound of Each Food Material.

EDIBLE PORTION. (Flesh freed from bone and other refuse.)		SPECIMENS. (Including edible portion and refuse.)	
Beef, lean, nearly free from fat,	679	Beef, round, rather lean,	1113
Beef, round, rather lean,	1237	Beef, sirloin, rather fat,	1351
Beef, sirloin, rather fat,	1797	Beef, neck,	1362
Beef, neck,	1697	Mutton, leg,	1428
Mutton, leg,	1749	Mutton, loin (chops),	2250
Mutton, loin (chops),	2689	Smoked ham,	2626
Flounder,	438	Pork, very fat, salted,	5023
Cod,	476	Flounder, whole,	167
Mackerel,	1066	Cod, dressed,	315
Salmon,	1481	Mackerel, whole,	568
Oysters,	352	Salmon, whole,	975
Cow's milk,	472	Salt cod,	481
Cow's milk, skimmed,	270	Salt mackerel,	1394
Cheese, whole milk,	3130		
Cheese, skimmed milk,	1786		
Butter,	5654		
Wheat bread,	1958		
Wheat flour,	2534		
Corn meal,	2475		
Oatmeal,	2803		
Beans,	2326		
Rice,	2492		
Sugar,	2755		
Potatoes,	655		
Turnips,	213		

Table VI. shows the equivalents in foot-tons of the potential energy contained in the nutrients of different food materials. The amounts of potential energy in the same weights of protein and carbohydrates are about the same. But a given weight of fat contains on the average more than twice as much potential energy as the same weight of protein or carbohydrates. Hence food materials which have the most fat contain the most potential energy. Thus in the fatter kinds of meat there are very large amounts of potential energy. The estimates of quantities of potential energy in food materials are based upon two classes of experiments. Those of one class are made by burning food materials in an apparatus called the calorimeter, those of the other are made by putting animals in the respiration apparatus, giving them different food materials, and noting the results. One of the most important facts shown by these researches — indeed, one of the most interesting results of modern chemico-physiological science — has been reached by late refinements of the methods of investigation. It is that the quantities of potential energy revealed in the materials of our food by the calorimeter agree exactly with those obtained by experiments with living animals. We have here a fresh evidence of the rational way in which the body makes use of the material placed at its disposal for nourishment.

A practical application of the principles thus explained is found in the study of dietaries. A great deal of attention has been paid to this subject in Europe, where the necessity for economy is much greater than in this country. Thus it has been found that an average laboring man doing a moderate amount of work is fairly well nourished if his food contains about 118 grams (4.2 ounces) of protein, 56 grams (2 ounces) of fat, and 500 grams (17½ ounces) of carbohydrates per day. This standard for the nutrients for a day's food has been reached by experiments with individual men, and by collating dietaries of large numbers of laboring people in the different countries of Europe. The quantities of nutrients in a considerable number of European and American dietaries are shown in table VII.

TABLE VII.

DAILY DIETARIES.

Quantities of Nutrients and of Potential Energy in Nutrients.

DIETARY OF —	Protein.	Fats.	Carbo-hydrates.	Potential Energy.
	grams.	grams.	grams.	Foot-tons.
Stan'rd for laborer at moderate work. Voit,	118	56	500	21221
Stan'rd for laborer at severe work. Voit,	145	100	450	23409
Poor sewing girl, London, England, . .	53	33	315	12614
Poor factory girl, Leipsic, Germany, . .	52	53	301	13479
Poor laborers, Lombardy, Italy, ...	82	40	362	15231
Monk, in cloister, ...	68	11	469	16006
Privy councilor, Marburg, Germany, . .	90	79	285	15785
University professor, Munich, Germany,	100	100	220	15576
Physician, Munich, Germany, ...	134	102	291	18696
Adults, with moderate exercise, England,	120	40	530	21099
Mechanic, Munich, Germany, ...	117	68	345	17553
Hard-working laborers, Bavaria, ...	132	51	583	23661
Hard-working laborers, England, ...	160	66	579	25314
Brewery laborers, Munich, severe work,	149	61	755	29690
Brewery laborers, Munich, severe work, exceptional diet, ...	223	113	909	39544
German soldiers, peace footing, ...	114	39	480	19439
German soldiers, war footing, ...	134	58	489	21493
German soldiers, war footing, extraordinary ration, ...	191	45	678	27660
French Canadians. Can., working people,	109	108	525	25036
French Canadians, Mass., factory operatives, etc., ...	119	202	551	32135
Other factory operatives and mechanics, Mass., ...	126	185	530	30638
Glass-blower, Cambridge, Mass., ...	95	132	481	24935
College students from Eastern States. Food purchased, .	161	204	681	37163
College students from Eastern States. Food actually eaten	148	185	681	35565
Machinist, Boston, Mass., ...	181	254	617	39141
Brickmakers, Middletown, Conn., ...	222	263	758	44906
Brickmakers, Massachusetts, ...	180	365	1150	61465

The food of poorly-paid laborers in England, France, and Germany is thus seen to be deficient in nutrients.

The dietaries of peasants in Lombardy, who live upon corn meal, were very deficient, especially in protein; they suffer terribly from a disease called pellagra. It is found that when they have, along with the corn meal, other food which supplies the lacking nutrients, the disease speedily disappears. The food of well-to-do English, French, and German mechanics and laborers was fully up to the standard,

while the ration of the German soldier for times of hard marching and hard fighting was considerably in excess of this standard. The results of the examinations of a number of American dietaries were given along with the European ones. The most striking feature was the large amount of nutrients which they uniformly contained. The amount of nutrients in the food of the French Canadians in Canada, in that of the same class of people when they had come to Massachusetts and worked in the factories; in the food of the Irish, German, and American factory operatives in the factories of Lowell, Lawrence, Lynn, Holyoke, and other places in Massachusetts, and in that of other people in Massachusetts and Connecticut, were illustrated in detail, the figures being based largely upon statistics collected by the Massachusetts Bureau of Statistics of Labor. There were no cases in which the quantities of nutrients did not come up to the European standard referred to. The majority largely exceeded this standard, so that the potential energy in the food supplied to mechanics, factory operatives, and laboring people in New England, as indicated by these dietaries, was in no case less, while in a number it was fifty or one hundred per cent more than in the European standard. The data at hand make it appear that not only well-to-do people, but the laboring classes, and even those whose income is relatively small in Massachusetts and Connecticut, are very bountifully provided with nourishment.

Two important inferences are to be drawn from these facts. One is that the food of people in moderate circumstances, as well as that of the rich, is apt to be very uneconomical pecuniarily, the materials being purchased at a much larger cost than is necessary. This superfluous expense is due in part to purchasing excessive amounts of food, and in part to the uneconomical selection of food materials. One of the worst phases of this bad economy is found in the habit of throwing away large quantities of food material. Of all civilized men the American is, perhaps, the most wasteful; and of the ways in which his wastefulness manifests itself, one of the chief is in his use of food. Another inference — and one of perhaps even more importance — is that we are very much addicted to over-eating, a habit which is doubtless fraught with great injury to health. At the same time it is very probable that there is an important connection between the bountiful food of the American workingman and the large amount of work which he accomplishes. This particular question calls for fur-

ther study. Doubtless the results of such investigation, rightly conducted, would throw very important light upon the problem of the ratio between wages and production.

Reference was also made to the food of the poor in Boston and other places. It was insisted that the people of the poorer classes are really least economical of all in their purchase and use of food, and that the instruction of the poor, and of people in moderate circumstances, in the elements of food economy, would be one of the most excellent ways in which knowledge may be utilized and charity exerted. One of the fortunate signs of the times is found in the work done in this direction in some of the schools in Boston, and in such work as that of Mrs. Richards in the Institute of Technology. The fact that these important problems are being taken hold of, and the results of scientific research applied in the ways mentioned, is extremely gratifying.

The meeting was brought to a close by a vote of thanks to the speaker.

MEETING 348.

The Micro-Membrane Filter.

BY PROF. W. R. NICHOLS.

The Creque System of Defecating, Storing, Circulating, and Employing Water for Domestic Purposes.

BY MR. ALLEN P. CREQUE.

The 348th and annual meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, May 13th, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, the Nominating Committee presented their report, and officers were elected for the ensuing year.

The report of the Executive Committee was read, and ordered placed upon the records.

The Meteorological Committee then reported through its chairman, Prof. Wm. H. Niles: —

REPORT OF THE METEOROLOGICAL COMMITTEE.

Prof. NILES said that the specific duties of the committee during the year had been few beyond the ordinary inspections of the Boston signal station, and reporting upon its uniformly good condition. The committee had, however, co-operated with others who were seeking to advance the study and practical application of meteorological science, and some noteworthy improvements had resulted. A too common use of the term *local*, as applied to rains and snows in the weather "*indications*," had been criticised, and the desired change had been secured. Also an important change in the dangerous wind signals had been determined. The chairman spoke of the frequent misinterpretation of the cautionary signal, and explained the significance of the flags being introduced. He said that the red flag, with a black center, is to be continued as a cautionary signal; but, instead of being displayed whenever there is a probability of a wind having a velocity of twenty-five miles per hour, it will hereafter signify that a wind of at least thirty-five miles per hour is anticipated. As a wind of given velocity may, at a certain locality, be a source of danger if it blows from a certain direction, and may not be a dangerous wind if coming from some other quarter, it becomes desirable that the probable direction of the wind be indicated. Hence a direction flag is to be displayed upon the same staff with the cautionary flag. A diagram was used to illustrate how the arrangement and relative position of the two flags may clearly indicate the quadrant from which the wind is expected. It is to be hoped that by this method the value of the warnings will be considerably increased.

The finely-equipped meteorological station upon Blue Hill, constructed and maintained by Mr. A. Lawrence Rotch, is giving valuable aid to the Signal Service, and gathering important data for the study of the climate of the region of Boston.

The New England Meteorological Society is successfully conducting observations upon temperature and rainfall in about one hundred New England towns. Prof. Upton, of Providence, is employing some of the data thus obtained in making a detailed study of the important storms which traverse the territory. Two papers upon this subject, which have already appeared, show in a conclusive manner that it is

largely through a better knowledge of storm laws that practical meteorology may be advanced. The study of the thunder storms of last summer, under the direction of Prof. Davis, of Cambridge, has given promise of valuable results from the much-extended investigations to be made the coming summer.

THE MICRO-MEMBRANE FILTER.

The President then introduced Prof. W. R. Nichols, of the Institute, who described the Micro-Membrane Filter.

Prof. NICHOLS said: The so-called micro-membrane filter, which I bring before you this evening, is the invention of one Friedrich Breyer, of Vienna. This filter does not claim to exert any chemical effect upon the water, but relies for its efficacy upon the excessive minuteness of its pores through which the water must pass.

The material employed is asbestos. The value of this material as a filtering medium is well known to chemists, and it is frequently made use of in the laboratory; but the material which we there use is not as fine or as elaborately prepared as that used in these filters. The asbestos is first carefully selected and ground in a mill. We all know how a sheet of mica may be split into thinner and thinner layers; in the same way the threads of asbestos may be split longitudinally into thinner and more delicate threads. Practically, this is accomplished by grinding the wet asbestos with about its own weight of crystallized carbonate of lime, the carbonate of lime being subsequently dissolved out with hydrochloric acid. The resulting asbestos pulp is then allowed to deposit upon cloth stretched in an apparatus so arranged that the pressure may be diminished beneath it, and the asbestos film, or membrane, thus produced is a very different thing from ordinary asbestos paper. While water will pass through the pores, the finest solid particles are arrested, the film being made very thin to facilitate the passage of the water.

[Drawings of the fibers of cotton, sponge, a thread of silk, a spider-web thread, and fibers of asbestos, magnified a thousand times, were exhibited on the board, showing very clearly the extreme fineness of the asbestos fiber.]

It is calculated that with only three superimposed individual layers of this asbestos film there would be in every square millimeter two and a quarter million pores, or openings, for the passage of water.

The asbestos films are laid upon nickel-plated metallic frames, put together in pairs so as to leave a space for the flow of the filtered water between them. In the form at first employed, the asbestos pulp was deposited upon each individual filter separately, and the filtering material could be cleaned or renewed only with difficulty, so that in this form the filter could certainly not come into general use. Now, however, the filtering material is placed on the outside, and furnished in films which can be renewed without much trouble. I will say, however, frankly that before the filter can find general adoption as a household filter further simplification will be necessary. I am informed that the manufacturers are now constructing filters which can be fitted into the faucets, and which will stand a pressure of four atmospheres, and deliver from forty to four hundred liters per hour, according to size.

Until within a few years the most that was seriously expected of a domestic filter was that it should *strain out* the minute particles of matter, living and dead, which were suspended in the water, rendering it unsightly and unpalatable. Now, however, a new standard is raised. The popular mind has become imbued with the idea that the substances which are dissolved in the water are not of so much consequence after all, but that the water is full of microbes and germs which ought to be removed, because some microbes or germs are pathogenic, and are injurious to human beings. A filter, then, to meet the enlightened demand of the moment must claim to remove these microbes as well as the grosser particles of suspended matter. Any decent filter will accomplish something in this line, if the water be filtered slowly, even the large sand-filters used for treating city supplies at the service.

The micro-membrane filter claims to furnish a water free from germs. Whether it will do this I am not prepared to decide. It will certainly remove very minute particles. I have here a filter which is immersed in water with which ultramarine has been mixed. It is calculated that the finest particles of the ultramarine are not more than from $\frac{1}{10000}$ to $\frac{3}{10000}$ of a millimeter in diameter. This coloring matter is removed completely by the filter. Another filter is delivering clear water from a water made turbid by fine clay, which ordinary filters will allow to pass, and a third filter is delivering bright and clear water from a rather foul infusion of hay.

Personally, I am quite content with this proof of the efficacy of the filter, and I think in its larger forms, with attached reservoir, it may serve a good purpose. Of course, in this country, these small filters which take an hour to filter a quart of water would be quite useless. No one will wait fifteen minutes for a glass of water to filter through; he would rather take his chances with a few more microbes.

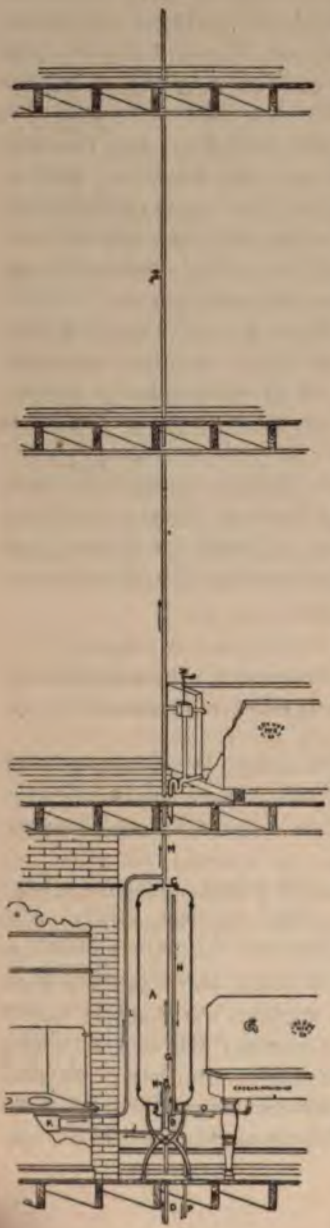
I do not lay so very much stress upon this matter of "germs," in the present connection. First, because there is no proof that the number of microbes bears any direct relation to the wholesomeness of the water; second, because a water furnished or used for domestic supply ought not to contain *dangerous* organisms requiring removal; third, because, even if it were possible to obtain a germ-free water by carefully sterilizing the whole apparatus and receiving the filtered water in sterilized vessels, such water would not be obtained in the ordinary use of the apparatus. I hope, however, for my own satisfaction to make some experiments on the material by itself, arranged for laboratory use, independently of the apparatus. In some experiments already made with the apparatus as arranged, I have not found it possible to sterilize by filtration an infusion of hay, although the filtered liquid was perfectly clear and bright as it came through the filter, and was received into carefully sterilized flasks.

THE CREQUE SYSTEM OF DEFECATING, STORING, CIRCULATING, AND EMPLOYING WATER FOR DOMESTIC PURPOSES.

At the conclusion of Prof. Nichols' paper, the President introduced Mr. Allen P. Creque, of New York, who read a paper on the "Creque System of Defecating, Storing, Circulating, and Employing Water for Domestic Purposes."

After a few preliminary remarks, the speaker exhibited a large sectional diagram of the common "kitchen-range boiler," with which he proceeded to explain and illustrate the serious defects in their construction, form, connecting devices, and their imperfect mode of circulating the heated water; also, a large number of other diagrams illustrating the construction, form, and connecting appliances of the Creque system of hot water circulation. The three accompanying illustrations, selected from the exhibit, and explanations, will assist in making the essential features understood. (See Fig. 1.)

FIG. 1.



The cold water supply, under pressure, is conveyed in the cold water supply pipe D to the compound coupling B, through which it flows into the connecting cold water supply tube E, and, pressing against the check-valve F, elevates it from its seat, and discharges through the interstices of the check-valve F laterally into the circulator A some distance above the sediment level, forming a cold water repository.

Cold water within the "circulator A" enters the inlet of the cold water circulation tube H above the level of the check-valve F, and also some distance above the line of sedimentary matter which may be resting upon the bottom end of the circulator, and is conducted through the compound coupling B into the cold water circulation pipe J, from whence it enters the water heater K, where its temperature is greatly increased.

The heated water invariably proceeds from the water heater K into the hot water circulation pipe L, and through the connected hot water delivery pipe M to any open hot water faucet above the circulator A.

If all of the hot water faucets are closed, the heated water will find its exit from the heater K through the hot water circulation pipe L, and be discharged through the coupling C directly into the extreme upper section of the circulator A, where its increasing accumulation will press downward, with a horizontal contact, upon the volume of cold water beneath it, forming a hot water depository.

When there is an accumulation of hot water in the circulator A, if a faucet on the hot water delivery pipe M should be opened, the hot water in the hot water depository will instantly commence to ascend through the coupling C and hot water delivery pipe M directly to the discharging faucet.

If a faucet be opened upon the hot water delivery pipe O, which is intended to furnish heated water for use upon floors level with, or below, the circulator, heated water from the hot water depository will immediately descend through the hot water delivery tube N, and, passing through the compound coupling B, will be conveyed by the hot water delivery pipe O directly to the discharging faucet.

Should a faucet be opened, simultaneously, upon each of the hot water delivery pipes M and O, heated water from the hot water depository will instantly proceed to both of the discharging faucets, impelled by an equal division of the pressure contained in the cold water supply.

Should the cold water supply be withdrawn in the cold water supply tube E, the automatic check-valve F will instantaneously rest upon its seat, formed by the discharge end of the cold water supply pipe E, and effectually prevent the return flow of the cold water from the circulator A into the cold water supply tube E.

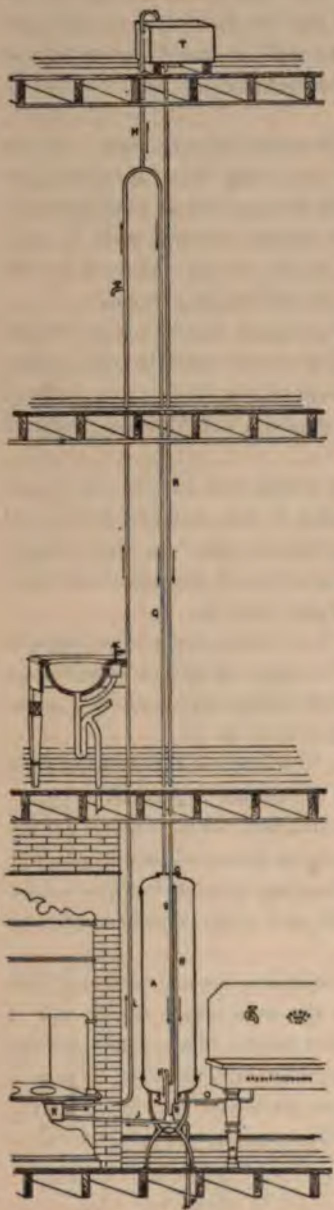
When the automatic check-valve F is closed, any undue pressure created by the expansion of water in the heater K will escape through the relief-valve tube G and the automatic relief-valve contained in the check-valve F into the cold water supply tube E.

Sediment is discharged from the circulator A through the compound coupling B and multi-cock into the sediment pipe P.

Incrustations, compact sand deposits, etc., which cannot be discharged through sediment pipe P, may be detached, taken out, and the circulator thoroughly cleaned by removing the coupling C and compound coupling B, which will provide two large orifices, or handholes, in the circulator.

Figure 2 represents a hot-water circulator with "return circulation" connections. Cold water from the cold water supply tank T flows downward through the cold water supply pipe R, and, passing through the multi-coupling C, is conducted by the connecting cold water supply tube S to near the bottom of the circulator A, where it is discharged laterally. Cold water within the circulator A enters the inlet

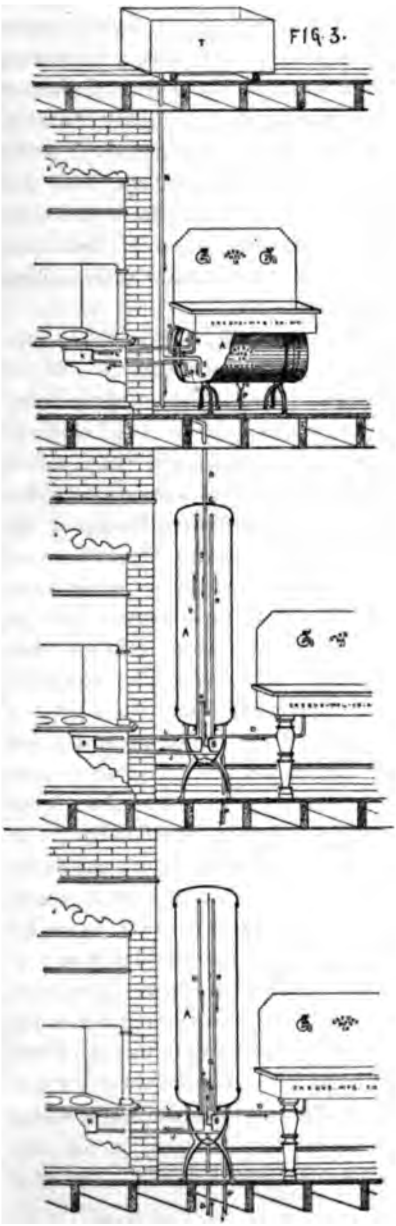
FIG. 2.



orifice of the cold water circulation tube H, and is conducted through the compound coupling B and its multi-cock into the cold water circulation pipe J, which conveys it into the heater K. The hot water from the heater K is conducted by the hot water circulation pipe L to the upper floor of a dwelling where it flows into the return hot water pipe Q which conducts it through the multi-coupling C into the extreme upper section of the circulator A. M is a vent pipe for the escape of steam, air, and expansion. Branch hot water delivery pipes are attached to the hot water circulation pipe L. Hot water within the circulator A, intended for use upon the same floor occupied by the circulator or floors below it, enters the upper end of the hot water delivery tube N, which conveys it through the compound coupling B and connecting hot water delivery pipe O to the discharging faucet.

In fig. 3 the pipe connections and circulation of the hot water circulator located upon the first floor is the same as that represented in fig. 1, with the exception that the top end of the circulator A is solid, and, consequently, there is no hot water delivery pipe attached to it. Also, the heated water in heater K is conducted by the hot water pipe L to the compound coupling B, through which it passes into the hot water circulation tube U, and is discharged within the circulator A near its top end. This circulator is especially designed

FIG. 3.



for "apartment houses" where the hot water is required only upon the floor occupied by the circulator.

The hot water circulator, illustrated upon the second floor (fig. 3), has the same pipe connections as the circulator upon the first floor of same figure, except that the cold water supply is furnished from a tank T upon the fourth floor. The cold water is conveyed in the cold water supply pipe R to the coupling in the top end of the circulator A through which it flows into the cold water supply tube S, and is discharged laterally into the circulator A a short distance above the sediment that may be resting upon the bottom end of the circulator.

The horizontal hot water circulator, illustrated upon the third floor (fig. 3), receives its cold water supply from tank T, located upon the fourth floor. The cold water supply is conveyed by the cold water supply pipe R to the multi-coupling C, secured in the end of the circulator A through which it flows into the cold water supply tube S, and is discharged laterally into the circulator above the sediment level. The cold water within the circulator enters the inlet of the cold water circulation tube H above the discharging orifice of the cold water sup-

ply tube S, and also above the sediment level, and is conducted through the multi-coupling C into the cold water circulation pipe J, and thence into the water heater K. The hot water proceeds from the heater K into the hot water circulation pipe L, and is conducted through the multi-coupling C and connected hot water circulation tube U and discharged within the circulator near its upper cylindrical side. Hot water for use finds its exit from the circulator through the hot water delivery tube N, the multi-coupling C, and connected hot water delivery pipe O, to any faucet situated upon either the same floor with the circulator or upon floors above or below it. Sediment resting upon the lower cylindrical side of the circulator is discharged through the coupling V and connecting pipe P.

The speaker remarked that the name "range boiler" is a misnomer when applied to a vessel known by that appellation. Water is never heated or boiled within it. The water is heated in the water heater, which generally forms one side of the fire-box of the range or stove, and is sometimes called a stove water-front, or a range water-back. The name hot water circulator he deemed more appropriate.

Mr. Creque said that these hot water circulators increased the number of superior materials from which hot water circulators may be successfully manufactured by providing a large orifice in each end of the circulator, which is indispensable for a proper internal galvanizing, enameling, forming and baking of circulators made of either galvanized iron, enameled metal, or of porcelain. The method of conveying and discharging the cold water supply into the circulator establishes an exclusive cold water repository underneath the hot water depository, agreeable to the law of gravity. It conveys and discharges the cold water supply directly into the cold water repository without passing into or through the hot water depository. It retains intact the entire volume of water contained in the circulator, circulation pipes, and heater, which insures an immediate, uniform, and uninterrupted delivery of hot water for use, and prevents sudden and injurious contractions and expansions of the circulator and its various connections, makes reversals of circulation absolutely impossible, and interposes a reliable, effectual bar to the dangers of explosions arising from an exhaustion of the cold water repository. Should steam attempt to form, the relief tube and its valve would allow it to quietly and safely escape from the circulator into the cold water supply

tube whenever the pressure within the circulator and its connections exceeds the maximum hydrostatic pressure of the cold water supply.

The lateral discharge of the cold water supply, within the circulator, some distance above its bottom end, promotes the speedy deposit, by gravity, upon the circulator bottom of the coarse vegetable, mineral, and organic substances contained in the feculent cold water supply. This produces a necessary and very important partial purification in the contents of the cold water repository. Entering some distance above the sediment level, it also prevents the disturbance or agitation of any sedimentary matter which may be resting upon the bottom end of the circulator. Only the purer cold water is permitted to enter the circulator and flow into the heater, as the inlet of the cold water circulation tube is elevated a considerable distance above the sediment level, and also above the discharging orifice of the automatic check-valve, seated upon the outlet end of the cold water supply-tube. Hence, it is impossible for either the sedimentary matter resting upon the circulator bottom end or the feculent cold water supply to be absorbed into the circulation and diffused throughout the entire volume of water within the circulator, thus polluting the hot water discharged for use, and inducing the formation of incrustations in all parts of the circulator and its pipe connections. By preventing the circulation pipes and heater from being coated and clogged with filth, it materially increases the production of heated water, and also its rapid circulation. It also saves much trouble and expense, otherwise necessary, in frequently taking apart the whole apparatus for cleaning.

The temperature of the water being increased in the heater, the heated water will immediately proceed directly to any hot water faucet, discharging either above or below the level of the circulator without passing into the circulator, or being chilled by contact with, or dispersion into, the cold water volume. An increase in its temperature compels the water to find an exit from the heater, and to advance directly into the extreme upper section of the circulator, where many of the finer deleterious substances, held in suspension and solution, naturally separate and descend by gravity to the circulator bottom, effecting a second and more thorough purification of the heated water. The heated water is generally retained a considerable time in the circulator, and also circulated many times through the

heater before it is discharged for use, which secures the destruction of organic life and an ultimate defecation of the successively heated water, which insures a wholesome, superior quality of hot water suitable for culinary, bathing, and laundry purposes.

It insures an instantaneous discharge, for use, of the hottest water, at any time, contained in either the heater or circulator. It also secures the immediate discharge of the entire volume of heated water when demanded for consumption.

It makes the sediment orifice in the circulator and its connecting pipe an independent passage which will allow the sediment to be conveniently, separately, safely, and frequently discharged from the circulator without interrupting the circulation and heating of water, or exposing the circulator or heater to the dangers of explosion. The ease and rapidity with which the sediment can be discharged from the circulator serves as an inducement to withdraw it frequently, and thus preserve the water within the circulator in the best possible condition.

An immediate, adequate, and reliable circulation and hot-water service is assured in every instance, whether the bottom-end of the circulator be fixed above or below the level of the heater.

The circulator can be placed near or remote from the heater without interfering with a positive, perfect circulation, and a reliable, satisfactory hot water service.

Its novel compound couplings render practical numerous modifications in the adjustment of the circulation and pipe connections to circulators of uniform construction, and readily adapts such circulators to all of the particular requirements demanded by each of the many positions that may be selected.

Respecting horizontal hot water circulators, the speaker said that the horizontal hot water circulator is peculiarly adapted for service in houses having a restricted floor area, as they utilize the otherwise useless space beneath the kitchen sink. They are adjustable to either side of the range or stove. If preferred, they may be suspended near the ceiling in a kitchen, directly above or on either side of the range or stove. A horizontal circulator placed in either of these five-named positions materially increases the unincumbered available kitchen-floor area, and also secures an immediate, reliable delivery of hot water for use. If suspended near the ceiling in a bath-room, it does not diminish the floor area, and will transfer the excessive heat from

the high, undesirable, and injurious temperature of the kitchen, and utilizes the continual radiation of heat from the "circulator" to maintain a mild, agreeable, healthful atmospheric temperature in the bath-room.

A vote of thanks to the speaker brought the meeting to a close.

MEETING 349.

The Latest Development of the Bessemer Process, or the Blowing of Small Charges.

BY PROF. T. M. DROWN.

The 349th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, May 27th, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, the President introduced Prof. T. M. Drown, who read a paper on "The Latest Development of the Bessemer Process, or the Blowing of Small Charges."

Prof. DROWN said: The question of the advantages to be gained in the blowing of small charges is still in its controversial stage, and the best I can hope to do in its treatment is to give the results of experiment and regular practice from both a chemical and physical standpoint, and to discuss the claims made for the method by those who believe it to be a valuable modification of the regular process, and also to give the criticisms of those who assert that there is really nothing new or valuable in the modification, except so far as special, geographical, and financial conditions may make its introduction desirable.

The discussion naturally assumes three divisions: —

First. Is the product of the Little Bessemer process better — that is, more uniform, more reliable, softer, more ductile, more easily

welded, more easily made — than the product of the regular Bessemer process, when using the same pig iron?

Second. Can the Little Bessemer process use inferior, cheaper, — that is, less pure pig iron,— than the regular process, and yet give as good a product?

Third. Can the Little Bessemer process exist side by side with the regular process?

At Avesta, in Sweden, where the Little Bessemer was first tried about eight or nine years ago, the converter is of the regular English revolving pattern, while in the Clapp-Griffith modification, in use in this country, the old Swedish stationary converter is used, with certain modifications; but both procedures have in common the small charges.

The description of the process at Avesta we owe to Prof. Josef von Ehrenwerth, of Leoben, in Austria, who visited these works in 1884. In Avesta there are two converters, movable on their axes by hand power. The bottom is secured by a screw. The hight of the converter is 51 to 54 inches, and the diameter 39 inches. The bottom is made of one piece, and contains about 90 tuyeres .12 to .13 of an inch in diameter, distributed in a circle of only eight inches; they are inclined at an angle of 45° to 50°.

The molds are filled directly from the converters, no ladle being used, and steel and cinder are poured out together. The blast is supplied by the same engines that supply the blast furnace, and are capable of blowing 15 lbs. to the square inch. The charge is taken directly from the blast furnace, and weighs from 375 to 1700 lbs.,— on an average, say about 1000 lbs., and 45 to 50 charges are blown in each converter in 24 hours, which includes the necessary changes of converters and bottoms. The blows seen by Ehrenwerth lasted 13.5 and 9 minutes respectively. The course of the blow is essentially the same as in the regular Bessemer process, except that it is completed with low pressure of blast.

Notwithstanding that cold charges are often blown, and notwithstanding the small amount of metal in the vessel, the steel is thoroughly and normally hot at the finish. At the end of the blow, 8 per cent of ferro-manganese is added, in small pieces, cold (the vessel being on its side), the mixture is rabbled with a stick of wood, allowed to stand quietly for some minutes, and then slowly poured into molds without any attempt to hold back the cinder.

As the results of a year's working (1879) there was 87.4 per cent of ingots produced to 12.6 per cent loss on the pig iron used, and since then a better record has been shown. There is no loss by skulls in ladles, and as the slag is poured with the steel into the molds, there is less loss at the top of the ingot.

The product is exclusively ingot iron, with carbon from .2 to .25 per cent. The amount of phosphorus in the Avesta pig iron, namely, .047 per cent, renders it unfit, it is thought in Sweden, for steel, and consequently only soft ingot iron is made. This sounds strangely to those who are compelled to use pig irons much higher in phosphorus. But, owing to the abundance of ores in Sweden, which contain only .015 per cent of phosphorus, or even less, this amount, .047, which would be considered in most countries extremely low, is thought dangerously high in Sweden.

Ehrenwerth, in describing the product, says: It is characterized by its excellent quality, by its uniformity in strength; but, above all, by its fibrous, or, better said, by its silky texture, in which respects it surpasses the best varieties of refined or puddled iron.

Analyses of the pig iron, and of the final product, are as follows:—

	Pig Iron.		Bessemer Iron.	
Carbon,	?	?	0.20	0.25
Silicon,	1.40	1.46	0.05	0.11
Manganese,	0.63	0.47	0.31	0.31
Phosphorus,	0.043	0.047	0.051	0.05
Sulphur,	0.01	0.00	0.00	0.00
Slag,	-	-	0.05 to 0.5	

Ehrenwerth considers this product to be distinguished chemically by the presence of slag and the absence of sulphur. He does not comment on the amount of silicon, which, indeed, in these analyses is not particularly remarkable. It is higher than we would expect, and

a chemist would naturally suggest that some of it was due to the intermingled slag.

The physical properties of this metal may be included in the following figures: 50,000 to 53,000 lbs. tensile strength to the square inch, 25 to 30 per cent elongation in eight inches, and 60 to 68 per cent contraction of area.

It is interesting to note Ehrenwerth's conclusions as to the essential characteristics of this process.

First. Small tuyeres, and a great many of them, in an inclined position, giving a better distribution of wind, and ensuring its complete utilization.

Second. Pouring from the *hot* retort.

Third. In general, a better heating of the retort, particularly in its upper part.

Fourth. High gas pressure in the retort, owing to its narrow neck.

As regards the intermingled slag, he says the same object would not be attained by pouring over the edge of a ladle, as the slag would then be partially solidified. Ehrenwerth evidently did not think the temperature of the final product any lower than in the ordinary practice. The absence of sulphur can scarcely be considered characteristic of the process, as there was practically none in the pig iron used.

It may be fairly said that Ehrenwerth's characterization of the process at Avesta is insufficient, and one must seek further for the explanation of the peculiar character of the product. The aspect of the process which most forcibly attracted Ehrenwerth's notice was the temperature developed, and in this connection it is interesting to learn that the plant was designed originally to make a sort of iron-sponge to use in the Martin process, and that the high temperature developed, and the fluid character of the final product, was a surprise to the projectors of the process. So satisfactory did the product prove that the intention of putting up a Martin plant was abandoned.

Shortly after Ehrenwerth's descriptions of the process in Avesta, experiments were made in blowing small charges at the Bessemer works at Prevali, in Austria, under the direction of W. Hupfeld.

These experiments were made in 1884. The first converter was constructed inside of a regular Bessemer vessel, and took a charge of 1300 to 2000 lbs. Notwithstanding that nine to ten minutes elapsed

in getting the pig metal from the blast furnace to the converter, the process proceeded nominally, with sufficiently high temperature, and the final product poured well. The time was 13 to 20 minutes, the pressure of blast 12 to 18 lbs. The cinder separated well from the metal in the ingot molds, and the ingot had a convex surface. The metal worked well, and was softer than the ordinary Bessemer metal made at the same works. Broken ingots showed very many small blow holes, but no particles of cinder were visible, although in taking the ingot out of the mold it was found completely covered with a crust of cinder about one-tenth of an inch thick. The ingots were converted into ship plates and boiler plates which were softer than similar metal with the same contents of carbon. The tensile strength in plates of three-tenths to five-tenths of an inch thick, unannealed, was 60,000 to 68,000 lbs., with an elongation of 22 to 26 per cent in a length of eight inches. When annealed it had a tensile strength of 54,600 to 57,000, and an elongation of 24.75 per cent to 27.75 per cent.

The softest metal made in this experimental converter contained .14 per cent of silicon, and .12 carbon, and the hardest .075 silicon and .71 carbon. Here again I suspect that there is an error in the silicon determinations owing to intermingled slag.

In a second series of experiments, with a new converter, near the blast furnace, it was found that it was not always feasible to take the iron direct from the blast furnace. Irregularities in the working of the furnace, poor fuel, etc., often gave rise to cold charges, and the process, as thus conducted, was unsatisfactory. Subsequently the small charge, 1400 to 1600 lbs., was taken from the ladle which supplied the large converters, and thus a large and a small charge were blown at the same time from identically the same iron. This gave an opportunity for a direct comparison of product, and it was found that the metal made in the small converter was always better than that blown in the large converter. Large quantities of the product of the small vessel were made into wire, sheets, and boiler plate. It was decidedly tougher than puddled iron, while its weldability was perfectly satisfactory.

Of 60 consecutive charges blown for soft metal in this converter, the average amount of silicon was 0.0281 per cent; of carbon, 0.1166 per cent.

Of these charges 18	per cent	had under		0.02	per cent	silicon.
48.6	"	"	between	0.02 — 0.03	"	"
18	"	"	"	0.03 — 0.04	"	"
11.6	"	"	"	0.04 — 0.05	"	"
3.8	"	"	"	0.05 — 0.055	"	"

The lowest silicon was 0.014 per cent, and the carbon varied from 0.08 to 0.16 per cent. Of the corresponding charges in the large converter, when the same degree of softness was aimed at, the average was 0.055 per cent of silicon, and 0.126 per cent of carbon. The extremes of silicon in the metal made in the large converters are, unfortunately, not given by Hupfeld.

From these comparative experiments, Hupfeld has shown that, when in the Little Bessemer process the carbon is brought down to the same point as in the regular process, the silicon is then more completely eliminated than it is in the regular process.

Let us now examine the variety of the Little Bessemer process which has been introduced into this country from Wales, under the name of the patentees, Clapp and Griffith. Their converter is of the original Swedish pattern, its peculiar features being, as stated by Mr. R. W. Hunt in a paper read before the American Institute of Mining Engineers, in February, 1885, a slag tap-hole, at such a hight in relation to the metal under treatment, that when the cinder is formed and it boils up as the blow progresses, it can run off, and thus be removed from contact with the iron, and will also be out of the way when the decarbonized metal is tapped into the casting ladle and the manganiferous alloy added. The tuyeres are situated around the body of the vessel, and enter the interior at some distance above the bottom. At first the converters were made with devices, more or less complicated, for shutting off the blast; but these are not now used. In practice, it is found that the slackening of the blast to a very low pressure suffices to keep the metal from clogging the tuyeres. At the completion of the operation the metal is tapped into a ladle, and is there mixed with the ferro-manganese, and then cast into ingots in the usual way.

The Clapp-Griffith procedure has, in common with that at Avesta and Prevali, the small charges, but it differs from them in having large side tuyeres, with low pressure of blast (five to eight lbs.), and in the practice of tapping off the cinder at the appearance of the flame.

No importance, I think, need be attached to the fact of the stationary converter, and to the fact that a ladle is used in casting.

The characteristic appearance in a Clapp-Griffith blow is the abundance of red smoke, which often forms dense clouds. The more the bottom is worn, which brings the tuyeres nearer to the surface of the metal, the more abundant is the smoke. It is clearly oxide of iron, and indicates an excess of air near the surface of the metal,—that is, more oxide of iron than the carbon and silicon can appropriate. This smoke has not been mentioned in the descriptions of the Avesta and Prevali blows, and there is less reason why we should expect it there, for in these cases the air passes through the mass of metal, and the oxide of iron formed at the bottom has an opportunity either to be reduced before it reaches the surface, or to combine with the silica of the lining. It is, however, conceivable that heavy overblowing, particularly when the carbon and silicon are nearly all oxidized, would give iron-oxide fumes even in bottom-blowing.

The product of the Clapp-Griffith converter is likewise characterized by low silicon, and it is claimed that this low silicon is a necessary result of this system of blowing. Many of the reported analyses give simply "trace" of silicon, a term variously used by chemists to express a very small amount. (It should be banished from the chemist's vocabulary, for when he cannot express an amount in figures he had better say "none.") But there are not lacking many accurate determinations, and these are all very low. Mr. McCreath gives some results as follows: 0.008, 0.004, 0.004, 0.009 per cent. These figures are probably not exceptional, but it would not be correct to say that all the product is as low in silicon. It may, perhaps, be safe to say that the Clapp-Griffith metal does not often exceed 0.02 per cent of silicon. Whether it is more uniformly low than that made at Prevali I cannot say, but I am inclined to think it probable.

Unfortunately, there are not on record many analyses of Clapp-Griffith metal low in phosphorus, and we cannot, therefore, compare its physical properties with those of the metal made in the small converters at Avesta and Prevali.

We have already seen that the blowing of small charges was not originally proposed with the idea that the product would prove to be of exceptional excellence; but if we admit that the product is exceptionally soft and ductile (as we certainly must if we accept the state-

ments of competent judges), what explanation can we give of the fact?

It is interesting in this connection to note the criticisms of Tunner, the distinguished Austrian iron metallurgist, on the Avesta process, and on the experiments at Prevali. He says he cannot see any reason why the Little Bessemer should give a superior product, and he asserts that the best way to make a soft ingot iron is by the Martin or the basic process. The only claim he will allow for the new variation is the low cost of installation, and local conditions must decide, in each instance, whether this low cost is true economy. He suggests that the reason of the soft character of the Avesta metal may be the result of the necessity of making a metal of perfect welding properties to remedy the imperfections of metal, and he intimates that there must be some disadvantages connected with the procedure, or it would have already found more general introduction. He does not discuss the question of low silicon, and while he claims that steel, in every respect as good in quality, and as soft and ductile, is made regularly at Neuberg, he does not inquire whether there may not be conditions in the small converter which necessarily tend to produce soft metal.

Ehrenwerth, in reply to Tunner, repudiates the idea that the Avesta works were driven to making a soft product to cover up the defects of the metal, but his defence of the fibrous character of the product is certainly weak. While he admits that homogeneous metal, when properly treated, is superior to weld metal, yet he argues that fibrous, that is, weld metal, is still preferred by many iron workers for various purposes, since its fibrous character is a guarantee of its softness and weldability. Avesta metal supplies this demand with a metal really superior to the ordinary weld iron.

There seems to be more misconception about fibrous iron than any other subject in iron metallurgy. Soft iron, whether homogeneous or welded, will give evidence of fiber if slowly torn apart by bending or stretching. What is a fiber? Simply an elongated mass or crystal of iron. When a fiber is broken short off by a sudden blow, what is the appearance of the fracture? Distinctly crystalline, with no trace of a fiber. To judge of the character of a sample of iron by means of the fracture, one must know how the fracture was produced. Now, it is true that in soft weld iron the fibrous character

of the metal is more easily developed and recognized, probably because the particles of iron are more or less separated by cinder. Shall we claim, therefore, that we improve the quality of iron by mixing it with a solid inert substance to break up its continuity?

When the question is put in this way, the absurdity of an admission seems evident, and yet there is one advantage of broken continuity, namely, that it opposes the transmission of fracture. Homogeneous iron or steel may be compared to glass, where an incipient crack will easily be transmitted through the mass. Weld metal may be compared to wire cable, in which a defect in one wire is confined to that wire, and is not transmitted to the others. Still, it seems clearly a retrograde step to mix cinder with ingot metal to get a fibrous product. The manipulation of ingot or homogeneous metal is, today, thoroughly understood, and no one hesitates to use it for bridge rods, steam boilers, or other similar purposes. If the metal is sufficiently soft and ductile, we need no slag to make it safe.

Ehrenwerth in reply to Tunner has no explanation to give of the superior quality of the Avesta metal other than the fact that low silicon pig iron is used, and that the wind is more thoroughly mixed with the iron, owing to the large number of very small tuyeres. It has long been a matter of comment that in Sweden pig iron is successfully blown that contains much less silicon than that used in other countries. Mr. Firmstone, of the Glendon Iron Works, Easton, Pa., has, I think, given a satisfactory explanation of this phenomenon,—namely, the much larger proportion of carbon dioxide formed in the gases of the Swedish converter. It is evident that when the carbon is merely burned to carbon monoxide there is much less heat generated than when it is burned to carbon dioxide. In other words, in Swedish practice there is more air blown in proportion to the amount of pig iron used than is usual elsewhere, and consequently some of the carbon reaches its highest point of oxidation. Side blowing, now generally practiced as a remedy for cold charges, is effective for the same reason.

If we look to the chemical composition for a solution of the question, we must accept Hupfeld's view, that it is due to the more complete elimination of silicon in the Little Bessemer. He says the only respect in which the soft Bessemer metal, made in Austria, is inferior to basic or Martin steel is in the somewhat higher percentage of silicon, namely, 0.035 to 0.06 per cent. Now, as we have already seen,

none of the metal made in the small converter at Prevali contained over 0.05 per cent silicon, and in two-thirds of it the silicon was not over 0.03, and it is generally admitted that the metal produced in the Clapp-Griffith converter is yet lower in silicon. I do not overlook the fact that in the analysis of Avesta metal, already given, the silicon is not especially low, but I am inclined to refer this to errors in analysis, as it is by no means an easy matter to determine silicon sharply in the presence of slag. From a recent article in the *Oesterreichische Zeitschrift*, by Fritz Fischer, on the Avesta process, we learn that the cinder is no longer poured into the ingot molds, as formerly, but that the greater part of the cinder is retained by inserting a brick in the mouth of the converter.

This proves well enough that experience has shown that there is no great improvement of the metal by mixing slag with it. It is interesting to note that the analyses of the final metal, since this practice was adopted, show only .014 per cent of silicon. Fischer remarks that it is an undisputed fact that the Avesta metal is of better quality than that made in the ordinary Bessemer converter, and that it ranks both technically and commercially with the Martin metal; but he attempts no explanation of the phenomenon.

Now, is there any reason for thinking that the conditions are essentially different in the small converter, so that it necessarily produces metal lower in silicon? It seems to be generally admitted that a very high temperature in the Bessemer converter is unfavorable for the complete elimination of silicon, and it is not improbable that silicon which has already been oxidized may be again reduced and united with the iron. Certain it is that pig irons, very high in silicon, tend to give ingot metal with high silicon, and that the extra-low silicon metals are generally made with pig irons low in silicon. The regular German Bessemer practice is to use highly silicious iron, and the steel produced is, in consequence, silicious.

Is this, then, the simple solution of the Little Bessemer, as Hupfeld suggests,—namely, that the charges blow cold? Surely, this would not be a difficult condition to imitate in the large vessel. We have no way of accurately measuring the temperature in the converter, and we can only judge by the appearance of the flame of the relative temperatures of different charges. To all appearance the flame in the small vessel indicates normally hot charges, and there

is no tendency, as far as noted, for the formation of skulls. There is, to be sure, relatively more heat lost by radiation in small charges than in large ones, and probably there is less opportunity for abnormally high heats being developed in the small vessel. As far as this goes, then, the tendency is to eliminate the silicon. But may there not be a counteracting tendency in the facility with which a proportionately larger amount of air may be forced into the small vessels? Still, if we admit, in the absence of any determinations of temperature, or of the composition of the gases, that the temperature in the small vessel is probably rather low than high, we have a favorable condition for the elimination of silicon. But this, clearly, is not a sufficient explanation to cover all cases.

In the small vessel, owing to the facility with which the charge can be treated with an excess of air, it seems probable that the cinder may be more basic, and that it may be more abundant. The formation of iron smoke in the Clapp-Griffith converter points in this direction. Unfortunately, there are no analyses on record of the cinder made at Avesta and Prevali. I have analyzed a sample of Clapp-Griffith cinder, made at Pittsburg, and found fifty per cent of silica. This is about the composition of some Neuberg cinders, but is much less silicious than cinders made at Bethlehem some years ago, as given in a paper by Mr. King, read before the American Institute of Mining Engineers, August, 1880.

Whatever may be the cause of the low silicon, it is certainly connected directly with the composition and amount of the cinder on the one hand, and the temperature of the vessel on the other. Now, while I am in doubt as to the result *per se* of blowing small charges, as regards temperature, I cannot help thinking that it tends to make the slags basic and abundant on account of the ease with which iron is oxidized.

As tending to confirm this view, I will cite an interesting description of the practice at Domnarfvet, in Sweden, some years ago, for which I am indebted to Mr. P. W. Moen, of Worcester, Mass.: —

"Some time ago, at the Domnarfvet Works, in attempting to turn down their converter, the turning arrangement, which was worked by friction, gave out, and the converter was held suspended in such a position that it was necessary to keep on the blast in order to prevent the metal from flowing back into the tuyere holes. It was naturally

thought that the blow would be a loss, but very much to the surprise of the engineers it was discovered that the iron was very soft, unusually so, and that contrary to the general rule with them, it was quite free from red-shortness, due to the presence of oxide of iron. The after-blow, if it may be so called, was made with a portion of the tuyeres (not all) above the surface of the bath, and undoubtedly caused a motion of rotation in the bath. I understand that since that time the practice of blowing in that way has been continued successfully at these works."

In a letter from Prof. Akerman to Mr. Moen, dated April 23, 1885, he says:—

"Your recollection of the occurrences at Domnarfvet was quite correct. Not only did they obtain in that way an unusually soft product, and free from red-shortness, but the iron, in casting into the molds, remained perfectly still and quiet, while ordinarily they were accustomed at that time to have considerable rising. The result of it was that when producing soft Bessemer iron they concluded to continue the blow for a short time with the converter turned down one-half to one-third. They continued this practice about a year, and the only disadvantage they observed in the beginning was a somewhat larger percentage of waste, which they submitted to meanwhile, partly to avoid the rising in the molds, and partly to get a softer product. After this Bessemer iron had come out into the market, complaints began to be heard about imperfections on the surface, and when these were found to depend on small, fine, exterior blow holes, which formed on the ingots, and did not always admit of being welded completely, the whole practice had to be abandoned, and, as far as I know, it is several years since they have practiced at Domnarfvet this partial turning down of the converter for an after-blow for soft iron. I do not know of this practice ever having been tried in any other works, and there is nothing in print concerning it."

Perhaps the practice of side-blowing, as now generally employed to remedy cold heats, was suggested by the Domnarfvet experience; at all events it is interesting and extremely suggestive that this practice at Domnarfvet was carried on successfully for a year for the purpose of making *a soft product*. Have we not here the essential conditions of the small converter, namely, a small depth of metal over the tuyeres? The greater waste, which was one of the causes

of the abandonment of the practice, indicates, too, the excessive oxidation of iron. In the Clapp-Griffith process the practice of tapping off the cinder also tends to increase the oxidation of the iron, and to form more cinder. Now what are the conditions in the regular Bessemer practice under which extra soft metal is made,—metal with carbon and silicon almost completely eliminated? I answer: the employment of pig iron, low in silicon, combined with side-blowing, or over-blowing. The latter, that is, the continuation of the blast after all the carbon has been burned out, necessarily forms oxide of iron, and thus tends, by making the cinder more basic and abundant, to retain all the oxidized silicon.

The conclusion seems inevitable that we can make ingot iron in the large converter that is as soft and ductile in every respect as in the small converter, by conforming to the conditions of the small converter; but we must, I think, admit that in the blowing of small charges the conditions for the production of soft metal are *inherent*, and that it may be fairly said that the Little Bessemer has merit of producing extra soft metal, because it cannot help it.

The pig irons thus far used in Europe in the Little Bessemer have been exclusively those used in the regular process. But in the Clapp-Griffith converter, in this country, pig irons, high in phosphorus. have been experimented on, and have given a metal of unexpected ductility. As the result of these experiments, it has been claimed that phosphoric irons can be successfully treated by this process. In Mr. Hunt's paper, already alluded to, he speaks of a shovel made from Clapp-Griffith metal, which had been turned over, and a perfect weld made. This steel contained: carbon, 0.11; silicon, 0.014; sulphur, 0.126; phosphorus, 0.346; manganese, 0.53. Steel, containing carbon, .08; silicon, .01; sulphur, .09; phosphorus, .50; manganese, .48, had the following physical properties: —

Tensile strength.	Elastic limit.	Elongation.	Reduction of area.
80,170	60,240	23 per ct.	32 per ct.
Lbs. per sq. in.	Lbs. per sq. in.		

These results are surprising and unexpected. It is true the metal is rigid, but it is more ductile than one would think such highly phosphoric metal could be. In seeking for a cause for the unex-

pected ductility, it was of course naturally suggested that the low silicon permitted higher phosphorus, for it is one of the well-established facts in steel metallurgy that, as the amount of carbon is lessened, one can safely increase the phosphorus. A similar relation may exist between silicon and phosphorus. There have not yet been enough facts accumulated with regard to these high phosphoric metals to enable us to decide whether they will come into general use. As far as I can learn the Clapp-Griffith plants in regular operation are not using high phosphoric irons. The prejudice against any ingot metal containing high phosphorus is too well founded to be overcome by a few instances of a tough metal, in which the phosphorus is abnormally high; and it will take a great deal of evidence to convince the metallurgist or engineer that phosphorus can ever be inert and harmless in iron.

Of the commercial aspect of the Little Bessemer not much need be said. The problem is a simple one, and will rapidly find its own solution. The tendency of competition in all manufactures is towards more expensive — that is, more stable and heavier — machinery, so that the product may be increased with diminished wear and tear, and diminished expenses for labor and superintendence. The cost of a first-class Bssemer works, with four large converters, is very great, and it must be in operation incessantly to work economically. That it would be impossible for a small, imperfectly-equipped works to exist side by side with a large one, it is needless to say, unless, indeed, its product were more valuable, or its raw material cheaper. Now, it is claimed that the Clapp-Griffith converter produces a more valuable product, using the same materials, or as good a product using cheaper materials. If these statements are admitted, we have ground for competition which will in time be settled by the ordinary course of trade.

There is another aspect of commercial question which is less connected with the character of the product, namely, in regions remote from the great industrial centers, a cheap, small plant may have a profitable existence with a near-home market secure from the competition of remote works. Again, an inexpensive plant directly associated with a blast furnace may find rational cause for existence where blast can be had from the ordinary blowing engines, where there is plenty of available power, and where the labor about the furnace can be utilized for the new plant without additional wages.

It is a matter of history, which is constantly repeating itself, that extravagant claims for new processes in iron or steel metallurgy meet in a surprising degree with a ready and hearty acceptance. All industrial processes begin and end in the matter of cost and value of product, and yet it often takes a costly experience to convince men of facts which are already at hand if they would but see them. In the early statements of the Clapp-Griffith process, criticism seemed to be silenced by the announcement of its dazzling results. The only analytical discussion that the process has yet had we owe to Mr. H. M. Howe, of this Society, who, by his article in *Science*, and in his remarks in the meetings of the American Institute of Mining Engineers, has done much to place the process in its true position. In classifying it as I have done, as simply a variation of the Little Bessemer, I think I have done the process no injustice, although it does differ in plant and practice from the Avesta process. But it seems to me that no new principles are involved in these differences. Whatever may be the final and practical outcome of blowing small charges, the discussion and investigation to which it has given rise will certainly add much to our knowledge of the Bessemer process, and enable us more completely to control the operation.

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CONTENTS.

NOTICE.

The Society of Arts, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce.

Regular meetings are held semi-monthly from October to May, inclusive, in the Institute building; and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending October 1, 1887, most of the business portions of the records being omitted.

For the opinions advanced by any of the speakers the Society assumes no responsibility.

LINUS FAUNCE,
Secretary.

Boston, June, 1887.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-FIFTH YEAR.

MEETING 350.

Steel for Warfare.

BY MR. H. M. HOWE.

The 350th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 14, 1886, at 8 P. M., Prof. T. M. Drown in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the chairman introduced MR. H. M. HOWE, who read a paper on "Steel for Warfare."

Mr. Howe first described what steel was, and showed by diagrams the effect of varying proportions of carbon on certain of the physical properties of iron. The tensile strength increases with the carbon, reaches a maximum, and again declines. The hardness also increases with the carbon, but it does not reach its maximum as soon as the tensile strength does. The property of being rendered alternately hard and malleable by rapid and slow cooling also increases with the carbon, reaches a maximum, and declines. The ductility, however, decreases as the carbon increases; and the melting point of the metal rapidly falls. The region of high ductility is one of great infusibility, and it is only within a few years that these ductile irons could be melted, and consequently the intermingled slag be removed.

The presence or absence of this mechanically intermingled slag marks the only difference between ordinary wrought iron and steels low in carbon. The steel of today offers the engineer an enormous

range of properties, and we have but a crude notion as to what particular degree of carburization, with its corresponding relation between strength and ductility, is best suited for many of the most important uses.

The speaker next took up some of the more important purposes for which steel is employed in warfare, showing what particular relation between ductility and strength was best suited to each case, and consequently the percentage of carbon the steel should contain. Thus, the shafts of marine engines should be made of a highly ductile steel, to resist the constant bending backwards and forwards consequent upon the distortion of the steamer, and also to resist the shock given by the connecting rod to the crank after the brasses become worn; and we find that shafts are made whose carbon varies from 0.10 per cent to 0.51 per cent. Steel for marine boilers should be very ductile, so as to enable it to be bent and flanged with safety, and to resist the strains caused by the unequal expansion of different parts of the boiler. In some hundreds of cases which have come under Mr. Howe's notice, the highest percentage of carbon in boiler-plate steel, he said, was 0.25, and the lowest 0.07; the average being 0.15 per cent. The plating of the hulls of iron steamers should also be ductile, so that in striking submerged rocks, etc., the steel will be bent in and not broken through, thus enabling the steamer to keep afloat. This steel has about the same degree of carburization and the same properties as that selected for boilers.

"In the case of great guns," Mr. Howe said, "it is not so clear from *a priori* considerations what degree of ductility and strength is needed. On the one hand the gun is subjected to something of shock on the explosion of the powder; to resist this shock ductility is needed. But on the other hand great strength is needed to hold in the pressure set up by the explosion. Moreover, while permanent distortion is permissible in the plates of a boiler or of a hull, it could not be tolerated in the least in the tube of a gun, which must retain its shape unaltered. The difficulty of judging of the best composition for gun steel may be recognized in the fact that makers of great intelligence have used steel with 1.18 per cent of carbon, which is hard enough for razors, and with 0.12 per cent, which is soft enough for rivets and horse-nails. Our present experience, which however is not fully ripe, seems to point to an intermediate composition of about 0.33 per cent

of carbon, which is decidedly stronger and less ductile than boiler-plate steel, as best suited to great guns.

Finally, as to armor plate. There are several kinds employed. Chilled cast-iron armor, such as Gruson's, is intensely hard, but as intensely brittle; hence it requires enormous thickness, with corresponding enormous weight, to resist successfully the impact of a great projectile. For land fortifications probably nothing can compare with these plates, but they are manifestly unsuited for the armor of war vessels.

Wrought-iron armor has so much less resisting power than steel of equal weight and thickness that it may be considered as out of the race.

Steel plates are of two kinds,—solid steel plates, which are homogeneous, and compound steel-faced plates with a hard steel face and a back of tough wrought iron or soft steel welded to the face. The armor plate must be hard enough to stop the projectile, and tough enough not to be shattered by its blow. The combination of hardness and toughness the compound steel-faced plate attempts to attain by the simple and promising expedient of welding a steel face so hard that the projectile cannot enter it to a backing so tough that the blow cannot shatter it. For such a face we apparently need great strength and hardness. In twelve recent instances the highest carbon which I find is 0.97 per cent, the lowest is 0.56 per cent, and the average is 0.70 per cent. In solid steel armor we need much greater ductility. The famous solid armor made by Schneider of Le Creusôt, has 0.43 per cent of carbon. This composition gives about the highest combination of strength and ductility.

When put to direct competitive test, the steel-faced plate has not shown as much resisting power as the solid steel plate. While in some trials at St. Petersburg the steel-faced plate came out rather better than its competitor, in the famous Spezia trials, as well as in those at Copenhagen, the solid steel showed by far the greater resisting power. The resisting power of the steel-faced plate may possibly be greatly increased, however, by altering the relative thickness of the steel and iron (at present about one-third of the thickness is of steel), by varying the ductility and hardness of its components, etc. There is one source of weakness, however, which is not likely to be removed. A plane of weakness, along which separation readily takes place, occurs at the junction of the steel and iron, even though they be actu-

ally welded together. In the compound plate the soft, tough back tends to bulge under the impact, while the hard, inflexible front refuses to bend and is flaked off.

There is one set of conditions where wrought iron may be of use. The wrought-iron turret of the Huascar, in the Chilian-Peruvian war, is reported to have been perforated by several 9-inch shots. The turret of the Huascar could be rotated after having been perforated, but had it been of steel it is altogether conceivable that the force of the blow might have distorted and jammed it so as to prevent its subsequent rotation. Now, though it is a terrible thing to have a shell perforate a turret and explode within it, it would be preferable to having the turret jammed, as this would completely disable the vessel.

In the manufacture of steel any degree of strength that is desired can be obtained by selecting a proper composition. But we obtain strength only at the sacrifice of ductility. Let us now consider certain methods by which strength may be increased without corresponding loss of ductility.

The first of these is by forging, which may be effected by the rolls, the hammer, or the hydraulic press.

But why do we forge steel? First, because molten steel contains a large amount of gas. Now, gases are in general vastly less soluble in solids than in liquids; hence, when the steel solidifies, a large amount of gas is given off. As the steel passes through an intermediate pasty condition before complete solidification sets in, the gases liberated are unable to escape and are imprisoned in the steel in the form of bubbles or blow-holes. In the second place, when the mass solidifies, the exterior cooling first becomes rigid, while the interior is still greatly expanded by heat. As the interior subsequently contracts it becomes unable to completely fill the rigid exterior, and contraction cavities arise. The first, and in my opinion chief, benefit from forging is that it closes these gas bubbles and contraction cavities, and to a certain extent welds their sides together, and gives the continuity which they had prevented.

A second benefit from forging arises from the kneading or working of the metal. We find that by forging masses of steel which are initially completely solid and free from blow-holes both ductility and tensile strength are increased, and we attribute this effect directly to

the kneading, the rubbing, and pressing together of the particles which takes place in forging.

Rolling is by far the cheapest method of forging. It consists of squeezing the piece which is being forged between a pair of horizontal cylinders. The effect of rolling on the quality of the steel is quite as beneficial as that of either of the other methods of forging. For the manufacture of plates nothing can compete with the rolls in cheapness and efficiency. The use of the rolls is restricted by the fact that we can only produce in them pieces whose cross section is uniform or nearly so.

The hammer offers the great advantage over the rolls that we can forge under it pieces of very irregular shape, but it, too, has a serious limitation in the fact that the effect of its blow is chiefly external. The distending effect of the blow on the interior of the mass is much less than on the exterior. Even the enormous hammers of Europe, the weight of whose falling parts rises to eighty tons, appear insufficient for thoroughly working large masses like great guns.

The largest American hammer, I believe, belongs to Park, Bro. & Company at Pittsburg, and weighs only 17 tons. Engineers often say that its effect equals that of a European 50-ton hammer, since its fall is accelerated by the pressure of steam on the upper surface of the ram which forms the hammer. But a moment's reflection shows the effect of the steam is simply to accelerate the fall of the hammer as a higher fall would, and we still have a mass which is light compared with the great European hammers, though indeed falling at great speed. But no speed will give a bullet the effect of a 1000-pound shot, and the high velocity of the Pittsburg hammer cannot compensate for its lack of mass in forging heavy pieces. Its blow remains a swift tap compared with that of a 100-ton hammer.

In forging under the hydraulic press, the lump of hot and plastic steel is placed in a mold whose interior has the shape which the exterior of the finished piece is to have, and a stamp, shaped so as to give the upper side of the piece the desired form is pressed down on it by hydraulic pressure. While the blow of a hammer chiefly distends the exterior of the piece struck, the slow, continued pressure of the hydraulic press works on interior and exterior alike, and forces the steel into every crevice of the mold like so much butter. There can be no question that for forging masses like great guns nothing can compete with the hydraulic press.

Sir Joseph Whitworth not only forges his steel in this way, but also subjects it, while molten, to hydraulic pressure, which in some cases rises to six tons per square inch; the objects of this liquid pressure are to eliminate blow-holes, and to improve the quality of the metal.

I have been unable to find that any improvement actually arises, since the best published examples of the quality of Whitworth's steel which I have met are equalled by those of the best uncompressed American steel.

Let us consider the effect of compression in the suppression of blow-holes. When the steel is first cast, and before solidification begins, it effervesces from the escape of gas. Now, pressure increases the solubility of gases in liquids, and it can therefore only retard or stop the escape of gas from the liquid steel, thus increasing the supersaturation which will occur when solidification sets in, the evolution of gas which will then occur, and the degree to which blow-holes will form. But it is quite otherwise with compression applied to the steel while solidifying. It may diminish the extent to which blow-holes form by actually squeezing gas bubbles out of the steel as they form. It may increase the solubility of the gas in the steel, and thus diminish the quantity of gas which is evolved; and it may compress the blow-holes which actually form, since the volume of a gas is inversely as the pressure. But as the solidification of the center of a large ingot only occurs after the exterior has already become rigid, it is by no means clear that even the enormous pressures used by Whitworth can completely suppress blow-holes. Nay, it is not certain that it can even compensate for the increased quantity of gas contained in the steel, owing to the compression applied while the metal was still a liquid.

While not denying the value of Whitworth's liquid compression, I consider that it has not yet been established, and it seems rash to add $200,000 to the expense of a gun foundry to obtain a result which can be accomplished by other means which do not increase the cost of the plant, and which affect the cost of production to but a trifling extent.

The formation of blow-holes in steel can be completely avoided by what is called the Terre-Noire process. By giving the steel a small amount of manganese and silicon, and by observing certain precautions

in its preparation, it solidifies without evolving gas. The Terre-Noire process, by preventing the loss of continuity caused by blow-holes, raises the tensile strength of the metal, probably without lowering its ductility; indeed, it appears to raise the ductility of steel as well as its tensile strength. It greatly lessens the advantages to be gained by forging. The engineers of Terre-Noire believe that with further experience they will produce castings whose quality will equal that of the best forgings, and of course at much lower cost.

We come next to the Rodman principle of gun manufacture. It consists in casting the gun around a water-cooled central core; the water circulating through the core rapidly abstracts the heat from the molten iron, and soon a thin cylinder of metal solidifies in contact with the core. Around this a second layer quickly solidifies, and on cooling powerfully compresses the layer within it. A third layer solidifies in turn and compresses the layer within it, and so on; thus, when powder explodes within its chambers, the whole mass of the gun instantly resists its expansive force, and we get the effect which is produced in built-up steel and wrought-iron guns by shrinking successive jackets around a central tube.

Eminent engineers who applied this principle to cast-iron guns very effectively during the war of the Rebellion are strongly of the opinion that it can be successfully applied to steel. Of course, this can only be proved by actual experiment.

The combination of this principle with the Terre-Noire process may be expected to produce an excellent gun, and one which could be turned out at comparatively small cost, and with great rapidity. This might be a matter of prime importance to us. A long time would be required to erect the enormous machinery needed for forging great guns, and after its erection the time required to forge, temper, fit, and assemble the pieces of a built-up gun would be very much greater than that needed for simply casting on Rodman's principle and boring.

In the matter of tempering, sudden cooling increases the hardness of steel at the expense of its ductility. The effect on tensile strength and ductility depends on the suddenness of the cooling, which in turn depends on the initial temperature of the piece to be cooled, and of the bath in which it is immersed, and of the specific gravity, mobility, specific heat, and latent heat of gasification of that bath. Immersion in mercury which is very dense and mobile causes very

sudden cooling; that produced by water, owing to its lower density, is much less, and oil, owing to its lightness, viscosity, and low specific heat, cools the steel comparatively slowly.

For steel of the composition employed for great guns, the best results are obtained by cooling the steel from a red or yellow heat in a bath of rape oil. The gun tube, for instance, is raised to a yellow heat in a vertical furnace; one side of the furnace, which is hung on powerful hinges, is swung open, and the gun is rapidly removed and plunged lengthwise in a deep pit filled with oil. Should the steel now prove to be too hard, it is again heated to a lower temperature, and again plunged in oil. Should it now be slightly deficient in strength, it is again heated, but to a slightly higher temperature, and again immersed.

MEETING 351.

Railroad Engineering Education.

BY MR. C. D. JAMESON.

The 351st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 28th, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, the President introduced Mr. C. D. Jameson, of the Institute, who read a paper on "Railroad Engineering Education."

MR. JAMESON said: The duties of the first railroad engineers were much more general than those of the present engineers. They located and built their railroads, designed their locomotives, rolling stock, and bridges, and when completed managed the road with success, and this without the aid of experience or precedent. Usually they were men who had had no early education or training in railroading, but possessed an indomitable will, unlimited patience, and a good stock of common sense.

We undoubtedly do things more quickly now than then, and in

many respects do them better; but this is due to the fact that we naturally profit by their experience, and also at the present time no one man does the whole of anything, hence he can do his particular part better.

In many branches, however, we have made but little, if any, advancement. This is particularly the case in the matter of location, where we seem to have copied the earlier engineers in their errors, but not in their habits of careful observation and study. The majority of our railroads are uneconomically located, and not only was the first cost of construction more than it ought to have been, but the loss in the operating expenses is enormous, and increases with increasing business. This loss is not, in the majority of cases, due entirely to the engineering profession, but to the mistaken policy on the part of the management of the railroad companies.

The expenses of the engineering parties on preliminary work and final location are very great, and for much of this expense the management can see no direct return, and there seems to be an idea abroad that most of the money spent in this way goes for theory, and is of very little practical use to the company. Therefore, the salary of the locating engineer is comparatively small, and his ability is frequently small in proportion. The number of his assistants is kept as low as possible, and the result is inferior work. The vital principles upon which the economic location of a railroad depends are not considered at all, or, at the most, in a very slight degree, and the smaller details upon which, to a great extent, depends the ultimate financial success of the road are left entirely out of account.

After the road is located, the management secures the services of the best construction engineer possible. This is as it should be; but no matter how great may be the abilities of the construction engineer, or how much he may save in overcoming the defects in location, still the greater part of the money merely passes through his hands as a paymaster, having been actually expended months before by the locating engineer.

In order that the railroad engineer of the future may be thoroughly competent, both in the "theory of economic location," and in the details connected with the work in the field, too much attention cannot be paid to this branch of education.

We are in an age of specialities. The engineering profession has

been subdivided so that we now have civil, mechanical, mining, hydraulic, sanitary, bridge, and railroad engineers. In order to reach distinction, a man must confine himself to his speciality, and if that be railroading, his time either as a student or as a man in active work will be amply filled in keeping pace with the age.

There seems to be a tendency among certain classes to sneer at an education, considering the time that is spent at college wasted, and that it might have been spent to much greater advantage in actual work in the field. Many instances are cited by these people, in corroboration of this belief, of persons who have risen to the head of their professions by their own exertion, without the aid of a college or technical education, and also of a large number of men who, having graduated from our finest schools, have accomplished nothing. The reason for this is not that these unsuccessful men lost anything by going to college, but they were greatly inferior in energy and ability to the others. Colleges do not profess to make brains, but simply to teach the man to use what he has to the best advantage; and the man who is successful without a college or technical education would, with this aid, have found the path to success much easier and shorter.

In the years which intervened between the first railroad engineers and those of the present they were considered a necessity in locating and building the road only. The road was then turned over to business men to manage. As long as the roads were small, and the repairs and renewals slight, this worked well. As the number of roads increased, and long lines and systems began to be formed, the increase of traffic demanded a large increase in the size and weight of the locomotives and rolling stock; this in turn necessitated renewals and additions to the road-bed and track, the replacing of the old bridges by new and heavier ones. This reconstruction in the form of renewals will never cease, and with it all the railroad companies have come to see the necessity of a permanent and reliable engineering corps. Thus the field of work for the railroad engineer has broadened from the transient work of locating and constructing the road to permanent positions on established roads, where there are abundant opportunities of making good use of his ability. But in order to take advantage of all these opportunities there is need of a much broader education in what we may call "railway science," which includes many branches as yet very little taught in our technical schools.

Let us now look at some of the items that should be included in a course of instruction in "railway science," or as it is commonly called a "special course for railway engineers." The length of the course should, if possible, be five years instead of four. The first two years should be devoted to laying a firm foundation in the general studies, particular attention being paid to mathematics, chemistry, and physics in their more elementary forms. The third year to the general study of civil engineering, and the last two years to a special study of railroads in all their branches. The third year's course should contain thorough instruction and practice in the field work of the railway engineer, in both location and construction. When the weather will permit, the field work should be pushed even to the point of sacrificing some of the work in the class room. The field methods should be taught exactly as they are now used in the best practice; the same terms used, the same organization of parties, and, most of all, the same discipline and strict attention to business. The greatest possible attention should be paid to the subject of location, in all its details in the field, and when the student has mastered as far as possible the principles that govern a railroad location in regard to the geography of the country, and understands the actual work of putting the line on the ground, then and not till then should he be instructed in those finer details and principles of the work called the "Theory of Economic Location," and upon which the true location of a railroad depends.

This "Theory of Economic Location" should be taught in the last two years. Also, there should be given a course of instruction in every branch of railroad construction, which should contain an amount of hydraulic and sanitary engineering sufficient to enable the person to build and maintain stations, shops, etc., and the proper handling of all the water that may be encountered in the construction and maintenance of the road; the "maintenance of way" in all its details, both in theory and practice; the proper management and economical distribution of large and small gangs of laborers; railway management as it applies to the operating of the road, such as internal management of the separate departments and their relations to the general management; the making up and running of trains; running and repairs of locomotives and rolling stock; station and terminal service; the relation between the railroad and the public; the finan-

cial management as to bonds, stocks, leased lines, consolidations, pools, etc.; and all the questions of railway transportation, legislative interference, and State ownership.

In the instruction in any branch of engineering the one thing to be kept prominently before the student is economy of design and construction. It is not enough to be able to design and construct a bridge of a certain length which shall safely hold up a given load, or a station that shall accommodate a given number of passengers and trains, but this should be done at the least possible cost.

If a person examines the courses of instruction in the different branches of engineering in the various technical schools in this country, he will be struck with the antiquated ideas and methods that still prevail in the majority of them. With but one or two exceptions there is no instruction given in railroad engineering proper, and the merest outline of the principles of location and construction.

There are undoubtedly some reasons why the schools are so much behind the times, and one of the most common, and at the same time the most serious, is the lack of money. Another is the low standard of admission, in consequence of which the whole of the first year is occupied in teaching what ought to have been learned before entering. The standard of admission is often lowered to attract students, but it is a suicidal policy, and soon ruins the reputation of the school. Every school should have an endowment large enough to pay all salaries and running expenses without depending in the least on the tuition of the students. Students should not be admitted until they are eighteen years of age, so that they will be able to fully appreciate the advantages offered them.

Still another reason is in the fact that the faculties of many of the technical schools have allowed themselves to get into ruts, from which it is difficult to move them. With the exception of the first, these reasons may be classed under the head of bad management, and the trouble can be easily corrected.

Every advantage should be placed at the disposal of the student. All the apparatus necessary for experiment of every kind should be provided; a good library containing every book of worth bearing on the different subjects; a good quiet reading room where all the engineering periodicals of the day are accessible. The student should be encouraged to do as much reading from a literary standpoint as

possible. It teaches him to think and to express his thoughts in a clear, logical, and grammatical manner.

He should be taught habits of application and the power of being able to concentrate the whole mind for the time being upon whatever work he has in hand. In other words, he should be taught to study, so that when he leaves he will not only be able to profit by his own experience as it comes slowly, but, what is far better, to profit by the experience of others, and thus at once advance to a point which it would take him years to reach by himself.

During the years spent at the Institute the student should examine as much as possible all engineering works that can in any way interest him while in process of construction.

In conclusion, let me say that the student should be so drilled that when he graduates he can have not only the diploma of the school, but, what is of more importance to him, can accept any position in his profession that offers, prove himself of use, and therefore a necessity to his employer, and earn a living for himself.

Prof. SWAIN, in the discussion which followed, spoke of the new field opening now to civil engineers in the actual management of railroads, and the consequent change in the instruction required. No line should be drawn between theory and practice. Theory should depend on practice, and in practice the necessary theory should be properly recognized.

Mr. G. R. HARDY, of the Boston & Albany railroad, after calling attention to the vast increase in railroads during the last fifty years, and the great dependence of our people upon them, remarked the ignorance of a majority of people on the geography of the principal roads. Instead of the well-worn question in our school geographies as how to get from Montreal to St. Louis by water, why not ask: "By what roads can the western grain be transported to the places of export?"

Mr. DWIGHT PORTER spoke of the tendency of civil engineers at the present day to enter more and more into the actual management of a road, and cited President Roberts of the Pennsylvania as a noted example.

Gen. WALKER advocated economy as one of the most important qualifications of a successful engineering career. Practical handling of materials one's self is surely conducive to economy. The English scientific schools are following our lead and introducing manual training more and more.

Hon. JACOB A. DRESSER queried whether England or America is ahead in scientific management of railroads. The conditions in the two countries are entirely different. There, small distances and plenty of capital; here, immense distances, and capital not so plenty.

MEETING 352.

Incandescent Lighting from Arc-Light Circuits.

BY MR. FRANK RIDLON.

Domestic Manufacture of Carbonated Beverages.

BY MR. CHARLES E. AVERY.

The 352nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, November 11th, at 8 P. M., Prof. C. R. Cross in the chair.

After the reading of the records of the previous meeting, and the election of new members, the chairman introduced Mr. Frank Ridlon, of the Brush Electric Light Company, who read a paper on "Incandescent Lighting from Arc-Light Circuits."

Mr. RIDLON said: In the past there has been a great gulf fixed between arc-lighting, so called, and incandescent lighting, the supporters of high and low tension, respectively, haviug no dealings with the opposite faction, knowing comparatively little and caring less about the respective merits of the two systems. This gulf is now bridged, and high tension and low tension may shake hands across the "bloody chasm." The merits of the two methods are combined, without the deficiencies of either. The great advantage of high tension is the fact that the current can be conveyed a long distance with a moderate cost for conductors; the advantage of low tension is its freedom from danger to human life.

In the new system of incandescent lighting from high tension currents, the high tension is used to convey the current along the line to the points at which it is wanted, while, where it is introduced into a dwelling house, or store, or other places where persons may have access to it, it is of low tension.

Now it is probably not necessary for me to explain to you how the ordinary arc and incandescent circuits are run. In the first, you will remember, the lights are strung along, one after another, like birds sitting on a rail, while incandescent lamps are interposed between two main conductors, like the rungs of a ladder. In the new system we have a combination of the two,— what is known as multiple series. This arrangement resembles a number of ladders in series, or one following the other,— the current passing along the line until it reaches one side of the ladder, then across the rungs of the ladder, or the incandescent lamps, to the other side-piece of the ladder, and then on to the line until it meets another ladder or set of lamps, and so on until the other side of the dynamo machine to that from whence it started is reached. It will thus be seen that the total current generated by the machine, whether 8, 10, 12, or 20 amperes, will pass through these rungs of the ladder, or lamps, which must, therefore, be of sufficient number and capacity to carry that current. The usual number of 16-candle-power lamps hitherto has been from seven to nine. For the sake of illustration and simplicity, let us assume a 10-ampere current, and ten lamps in each multiple, each requiring one ampere of current, and, say, 50 volts of electro-motive force. Now, as long as these ten lamps are perfect, each will carry its due proportion of current, and all will go well. But suppose one of these lamps to break, either from accident or old age, what follows? That lamp, of course, being unable to carry its proper quota of current, the remaining lamps have to carry it if it is not elsewhere provided for; and the means of conveniently and safely providing for it is just what all the endeavors of inventors and others who in the past have attacked this problem have been directed toward devising. And this brings me to the main point of my subject. Consider what the result of leaving such a multiple unprotected would be. When the first lamp gave out, the remaining ones would still have to carry the same current as the whole of them had previously taken, with the result that those lamps would have to carry more than they could safely stand. Another lamp

would soon give way under the strain, and the remaining ones would still have to carry the whole current. Lamp after lamp would go, until the last survivor had collapsed, and then the line would be opened, and the sudden opening of a line carrying some ten amperes at a pressure of from 1000 to 3000 volts generally gives rise to trouble. It is, therefore, from a practical and economical point of view, absolutely necessary that some method of protection should be employed. Now, what is it to be?

Various different devices have been employed. The Thomson-Houston Company have used a "distributing box" which met with a certain amount of success, but has gradually fallen into disuse. It is said that this Thomson-Houston device involves an unnecessary and extensive system of wiring, which is a serious drawback both in the matter of expense and in the complication of the installation. Mr. Brush has also introduced a multiple series cut-out, which is certainly extremely simple, in fact, too simple; for, in this arrangement, as well as in the Thomson-Houston device, at times a complete extinction of all the incandescent lights is liable to occur,— a result which cannot be admitted in practice.

The principal merit, as before indicated, of the high tension system is the low cost of conductors; the main advantage of the low tension being its flexibility, its safety, and its suitability for domestic, store, and office illumination.

The nearest approach to perfection in the line of low-tension distribution at long distances with which I am acquainted is that recently introduced by a company which we may really consider a Boston company, the Sun Electric Company, of Woburn, Mass.

By means of the system devised by Mr. Slattery, the electrician of that company, incandescent lamps of almost any candle-power can be operated from the ordinary arc-light circuits which now cover Boston with a network of wires. This company has shown that the matter has been brought beyond the stage of experiment, inasmuch as the Brush Electric Lighting Company, of Boston, alone have, by means of this company's system and apparatus, been enabled within the past two or three months to supply considerably over 1000 incandescent lamps to their customers, and these are today in actual and successful operation in this city. 1500 lamps are in operation in Rochester, N. Y., on the ordinary arc-light circuits, several hundred in Ports-

mouth, N. H., others in New Haven and Bridgeport, Conn., and in many other places, and their number is increasing daily. The practical working of the system is therefore beyond dispute.

To explain the system and circuits fully in a paper like the present would be impossible, and necessitate a number of diagrams; the results, however, I can put before you. The mechanical part consists of a "distributing," or more properly speaking a "protecting," box interposed in the arc-light circuit just as an arc lamp is, and from which are led the wires supplying the incandescent circuit and lamps or motors. This box contains two or more solenoids or regulating electro-magnets, controlling a series of contacts connected with resistances which are individually switched into circuit on the extinction of a lamp.

The circuits are usually arranged to operate 45 to 50 volt lamps, taking about an ampere of current each, and thus allowing of from one to eighteen lamps, there being, when more than nine lamps are in operation at normal incandescence, 90 volts in the circuit of incandescent lamps. In the ordinary box the circuit has to be switched over by the consumer from 45 to 90 volts when he requires more lamps than nine. If, however, the circuit be at 45 volts, and nine lamps are in circuit, switching a tenth lamp in will do no harm, but the current of the machine being constant, the lamps will not have sufficient current supplied to them, and will consequently become dim, thus indicating to the consumer that he should turn on his 90 volt circuit, to do which he has simply to turn a key or handle projecting from the box, which is kept closed and locked to prevent meddling with it. When the tenth lamp (any lamp in the circuit may be the tenth) is turned out again, the box will automatically switch the circuit back to 45 volts, thus saving energy and cutting out the resistances theretofore protecting that part of the circuit.

The whole of the lamps in the group of incandescents may be turned out without injury to the protector or the general circuit, though it would not be economical to do so; when it is desired to turn out all the lights, for the night or otherwise, the box is cut out of the circuit, and the current passes by. When it is wished to use large lamps, *i. e.*, 65 or 70 candle-power on a box, they are connected to the two outside wires of the three (No. 12) main lines leading from the box, which is then turned to 90 volts.

By a slight alteration of the disposition of the circuit, 8 or 10 candle-power, or smaller lamps, can also be operated from the box, thus permitting of the conjoint and simultaneous employment of almost any combination of lamps.

The operation of the box when lamps are turned off is simple. The two solenoids or coils on the right and left of the box are so adjusted that when all the lamps are in operation, the spindle in continuation of the armature will rest lightly on the top contact or spring, the circuit of resistances being then open. If, now, a lamp be turned off or break, more current will be shunted through the solenoid of that side, and the armature be further attracted within the core, and cause the top contact to touch one beneath it, thus closing a circuit though one resistance, taking up the current of the broken lamp, and preserving the balance of the circuit. If another lamp be turned off, the armature will be still more strongly attracted and depress the first and second strips so as to make contact with the third, thereby switching in a second resistance equivalent to a lamp, and so on, until all the lamps are put out of circuit and all the resistances thrown in.

An arrangement or disposition of circuits and means of protection such as this system offers is new in practice, there having been experienced in all the attempts hitherto made to operate lamps on this principle some difficulty or other which has prevented their commercial adoption and use. It is clear that the time has now arrived when some system of this kind must be adopted for localities not densely populated enough for the simple multiple circuit, and where the arc-light is unsuitable. This system will enable miles of arc-light wire now unproductive to be made a source of revenue. It will be remembered that in this system the introduction of additional lamps does not mean additional weight of conductors; all that is necessary in such cases being an increase in the electro-motive force of the circuit. The drop of the potential, moreover, is small and constant, as in an arc-light circuit.

It has been said that high tension circuits are dangerous. This is only the case where the line has been broken by some means, and the circuit thereby opened, or in the event of a ground frequently due to carelessly disposed outside main lines. In this system the circuit is never opened, but is always continuous; there never being in any

multiple more than the pressure necessary to operate the lamps, usually not over 50 volts, which is of course harmless. On this question of safety, the following remarks of Prof. GEO. FORBES are interesting: —

"Now a great deal has been talked about the danger of introducing high pressure in electric distribution. I think that I shall find general agreement among competent people when I say that a great deal of what has been talked in this way is pure nonsense, and that high pressures are not in the least more dangerous than our present systems of illumination; that if we have to bring high pressure of electricity through a district, those pressures are confined to the wires, and it is only in the case where there is disgraceful negligence of duty, and a disgraceful leakage towards the earth in some part of the system, that it is possible for anybody to receive a dangerous shock from the wires of such a system. The wires which conduct the electricity into a house of any of these high potential schemes can never have a greater difference of pressure between them than what is required for the lamp; that is, in the present state of affairs, something like 100 volts. We will say that is the highest pressure there can exist between the two wires, and it seems almost incredible that there should ever be allowed to be a leak in the system so great that when a person touches one of the wires he should have a high current flowing through his person which would be dangerous. If we are to abolish the idea of using high potentials simply because of this vague notion that some time a shock might be experienced, we might as well abolish the whole system of gas lighting, because it is possible that people can go into rooms where there is a leakage of gas with a lighted candle. The danger from gas is infinitely greater than that which can ever come from high potential electricity, and the difficulty of detecting a leakage of gas is likewise infinitely greater than the difficulty of detecting a leakage of electricity. A properly organized system of distribution of electricity at high potential would render a severe shock to any person absolutely impossible, and that is the point which needs to be dwelt on very strongly at present, because so much has been talked about the dangers of high potentials." (Cantor Lectures, Society of Arts, February 16, 1885.)

When the connections to the box are made the circuit is always closed, either through the lamps or the resistances, and to open the

line it would be necessary for a person deliberately to set to work to do it.

Another advantage of this system is that, in case of an accidental short circuit occurring in the incandescent group, there is less liability to injury by fire than in the simple multiple system, as, instead of an enormous current of perhaps 200 or 300 amperes rushing to the spot, producing a corresponding effect in heat, there can here only be some 10 amperes or so, according to the current of the machine employed.

In cases where it is desired to provide an "all night" circuit of say two 16-candle-power lamps, this can be done without any waste of energy in the circuit.

Another advantage of this system is that, in cases where it is desired for any reason to modify or vary the intensity of the light of the lamps, by a simple switching device the lights can be toned to any degree required; and, unlike other systems, in the event of a reduction of illumination, there is a corresponding reduction in the energy consumed. This is especially applicable to theatrical purposes, and has been practically tested in that connection, and is now in actual working operation with the most satisfactory results.

In addition to the ordinary 9 to 18 lamp box with three multiple wires, protecting boxes with a larger number of incandescent multiples, according to the lights required and the exigencies of each particular case, are used.

Having now touched upon those high tension incandescent systems which call for special notice, I will be told that the same fundamental objection prevails in all alike, namely, the use of equivalent resistances to the lamps and the introduction of those resistances into the circuit as lamps are switched out or burned out, thereby involving a great waste of energy.

Yes, I grant this is a great objection, however much we may try to modify it, even though we have the advantage of long-distance transmission. But who is bold enough to say how long such a state of things is going to exist? No doubt at all about the fact that the ideal high tension incandescent system is that which will require no resistances, as in the case of low tension incandescent distribution, and that, as in the latter case, lamps will be turned on and off at will without introducing any resistance in the circuit to take the place of the switched out or burned out lamps. Such a high tension incandes-

cent system, however, has always been considered as belonging to the category of the "philosopher's stone," and as being too good to be true; but how many of those supposed to be too good things have proved true? how many apparently insuperable difficulties have been overcome, and unsolvable problems have yielded their tardy solution before persistent and ingenious application? May we not, therefore, reasonably look forward in happy anticipation of the time when the ideal high-tension incandescent system shall be known and used in every town and district throughout the country, dispensing its incalculable benefits wherever civilization finds an entrance, illuminating our homes with the purest and sweetest rays that nature has given to man for man's utility?

In the discussion which followed the paper, Mr. C. E. AVERY suggested that the use of the volometer, which indicates a variation of one ten-thousandth of a degree Fahrenheit, might in some way be operated by the increase of heat when one lamp in a multiple failed, and shut off the extra current and turn it back on the line.

Prof. CHARLES R. CROSS said that the Siemens pyrometer might be used in some such way as Mr. Avery suggested for automatic regulation.

Dr. SKINNER remarked that, as the current on the multiple series line must in any event be constant, any such device would have no practical use.

Mr. AVERY replied that he had in mind a circuit carrying an alternating current passing through the secondary of a Ruhmkorff coil, the induced current from the other coil being employed to operate the lamps. In this second circuit such a thermo-regulating device might be used.

Mr. G. W. BLODGETT: How is it possible to run two 16-candle-power incandescent lamps in circuit with arcs without wasting current?

Mr. RIDLON replied that a distribution box for two lamps was provided; if one lamp broke or was turned out, an equivalent resistance was thrown into the circuit. This was accomplished by using lamps suited to the current, two lamps being made to stand the whole current of the line.

Mr. KIMBALL, of Woburn, explained from diagrams the various multiple-series cut-out boxes.

Col. E. H. HEWINS: What would happen in the event of the solenoid of the distributing box failing to work?

Mr. SLATTERY replied that its construction was such that he could conceive of no possible way in which such a contingency might happen. For if one urges that, the solenoid failing to act, one might open the line by turning off lamps, it must not be forgotten that, when nearly the whole multiple was turned out, the potential at the switch terminals would rise so much that the current could not be broken, but would make a path for itself through the switch.

DOMESTIC MANUFACTURE OF CARBONATED BEVERAGES.

The chairman then introduced Mr. CHARLES E. AVERY, who exhibited his apparatus for the domestic manufacture of carbonated beverages.

Mr. Avery's apparatus is exceedingly simple, being composed of three soda bottles with ingenious attachments; in one bottle a new non-acid, harmless compound slowly evolves carbonic acid gas, which, passing into the other bottles under pressure, is absorbed by the liquids in them. The compound used to make the gas is of such a nature that at ordinary temperatures the pressure cannot rise above a certain safe pressure.

He showed how it is charged, how the bottles are disengaged, and the apparatus at once run again with fresh bottles, while those first charged may be in the ice-chest or in use; how different drinks can be charged at once, and small quantities drawn as desired. He also said that ginger ale, carbonated milk, plain soda water, etc., could be made with great facility.

Samples of a soda lemonade made with lactart in place of lemon, and of champagne cider, charged by the apparatus, were given to the persons present.

A vote of thanks to the speaker brought the meeting to a close.

MEETING 353.

The New Art of Electric Welding.

BY PROF. ELIHU THOMSON.

The 353rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, December 9th, Prof. C. R. Cross in the chair.

After the reading of the minutes of the previous meeting and the election of new members, the chairman introduced Prof. Elihu Thomson, of the Thomson-Houston Electric Company, who read a paper on "The New Art of Electric Welding."

Prof. Thomson said: Hitherto, about the only metals which have been welded with facility by the ordinary method of heating and hammering have been wrought or soft iron, steel. platinum, gold, and a few others. So far as I am aware, cast-iron, brass, gun-metal, and bronze, German silver, zinc, tin, lead, aluminum, and several other metals less commonly used, have not hitherto been welded; and even with copper, which softens readily by heat, the welding together of two pieces, though not impracticable, has been so difficult as to be seldom tried. Much less, indeed, has it been generally practicable to weld pieces of unlike metals together, although a few exceptions exist.

Again, it can be truly said that very small pieces even of iron can scarcely be welded in the ordinary way on account of the rapidity with which they cool or are reduced below the welding temperature.

In electric welding, however, some of the metals which it was before impossible to weld become most easily dealt with; such are cast-iron, brass, and bronze, zinc, tin, etc. Copper, formerly welded with so great difficulty and uncertainty, unites with great ease and certainty. Iron, steel, platinum, and like metals, formerly known as weldable, are with great facility welded electrically. Thus far I have not tried any pieces of the same metal and failed to secure a weld. When, however, the pieces are of different metals or alloys, failure may result from too great differences, either in their temperature of softening or in their specific electrical and heat conductivities.

Before describing the details of my process, it may be briefly stated to consist in forcibly pressing together the bars or other pieces to be joined or welded, and then passing an electric current of large volume through the pieces, a small portion of the bars on each side of the place of abutment serving as a path for the current. The resistance to the passage of the current at the meeting-point of the bars gives rise to a welding heat at this point, and the pressure causes a thorough union, and generally a slight expansion at the union, caused by the approach of the pieces under the pressure. The uses are certainly not few, and an enumeration of some of them may be made. One of the most evident applications is in joining, end to end, wires of copper and iron for various purposes, such as in forming coils of magnet, and in telegraph, telephone, and electric-light lines for the avoidance of clumsy or resisting joints.

I have here for exhibition wires of copper and iron of varying sizes, with electrically welded joints, some of which wires have been bent and twisted without showing any sign of rupture at the weld. There is no reason why very heavy wires or bars may not be so joined by using sufficiently powerful apparatus. The largest diameter of copper rod thus far dealt with measured seven-sixteenths of an inch, and of steel seven-eighths of an inch, and, so far as can be determined by estimation, required a current of over 20,000 amperes to flow through it, which is probably a much larger current than has hitherto been produced in any single conductor or machine. Such a current will weld bars of steel or iron nearly one inch in diameter. This difference between the sizes of iron and copper welded by equal currents is due to the less resistance of the copper, and the greater facility with which it conducts heat away from the junction during the operation.

Another obvious use of the new method is in butt welding of metal tubes or pipes (examples of iron pipes of various diameters, brass and copper tubes, joined end to end, and a lead pipe with two joints, which pipe had been much bent after the joining, the joints being still perfect, were here exhibited).

In making or repairing endless bands, such as band-saws, wheel-tires, barrel and tank hoops, the electric weld promises to be of great utility, as will be understood from some specimens of such work here shown. Analogous to this is the heating and welding of chain links, as also exemplified by the specimens of work before us.

There is, also, a very wide field of usefulness to be found in the manufacture and repair of tools and machinery.

As examples of such work I may mention the lengthening of screw-taps, drills, reamers, augers to any desired degree; welding new drills and reamers to the taper shanks of old and worn out drills and reamers; and in general welding steel pieces to steel or wrought iron, or even cast iron, bodies of tools.

I have united the ends of wires less than .02 of an inch in diameter, and the larger size of pieces dealt with has been only limited by the power of the apparatus at command. I have reason to think that the actual fuel consumed in effecting a weld by electricity is less than in the ordinary furnace processes, and this is due to the very small time consumed in the operation, the application of the heat to the metal only at the weld, and the consequent very small loss by radiation and conduction during the operation. The pieces are not required to be manipulated during the process, a great advantage in the working of large pieces.

Having thus reviewed the possible applications as they now present themselves, let us turn to the operation itself.

In electric welding the energy given by fifty thousand amperes of current and half of a volt will weld a bar of steel or iron of about an inch and a half in diameter, so far as I have been able to estimate the conditions. There is quite a difference between the way the power is used in running electric lights and in welding. Lights demand the power continuously, while in welding the energy is demanded for a comparatively short time, varying from a few seconds to a half minute or thereabouts.

The apparatus here presented to the notice of the Society will now be described. The smaller apparatus consists of an induction coil composed of a core of iron wire about twelve inches long, and two and one-half inches in diameter, around which has been wound a coil of primary wire, and outside of that a coil of sixty-four wires, No. 10, laid parallel, and passing only eight times around the core. The ends of the secondary strands so formed are bolted down to copper plates, upon which the clamps for holding the pieces to be welded are mounted. These clamps are formed at the upper part of comparatively heavy blocks of metal. One of those blocks is arranged to slide upon its copper bed plate, and is guided so as to move in a straight line towards the other

block under the action of a spring which is adjustable. This permits the two pieces to be joined to remain in alignment during welding. A cam is arranged to be turned so as to separate the blocks and hold them apart during the placing of the pieces in the clamps.

The primary coil is traversed by currents from an alternating current generator in the basement, and the strand of sixty-four wires and eight convolutions gives the secondary current of large volume and low electro-motive force for welding. The resistance of the secondary coil taken alone is approximately .00015 ohm.

In the other apparatus which I have here the construction is different, and much larger work can be dealt with. The primary coil is a large open coil or ring, about twelve inches in diameter, made up of many turns of insulated copper wire. The secondary is a single bent copper bar, making only one turn outside the primary coil, and the terminals of this single heavy convolution are bent outward and provided with powerful screw clamps for holding the pieces to be abutted. The clamps are made movable towards and from each other by thinning and broadening the large bar at the middle of its circular portion farthest from the clamp, so as to give to it a certain degree of flexibility. The clamps are drawn together by a powerful screw and spring, so that the desired pressure for forming the weld may be given, and another screw is provided for forcing the ends bearing the clamps apart when pieces are to be inserted in the clamps preparatory to the passage of current.

Both the primary coil and secondary bar are wound over with a great mass of iron wire, which passes through the open axis of the coil and over the exterior, thus forming an endless core to both the primary and secondary conductors. These conductors are virtually enclosed in a tube or wrapping of iron wire. The iron core is wound on another iron guide or casing, which keeps it from bearing upon and interfering with the free movement of the parts of the secondary bar carrying the clamps.

The calculated resistance of the secondary bar is about .00003 ohm.

The alternating currents passed through the primary coil produce, of course, rapid reversals of magnetic polarization in the iron wire sheath of the coils, and result in a transfer of energy by induction to the circuit of the secondary, the transfer being attended with a

small percentage of loss. A current of a little over 20 amperes and 600 volts in the primary may produce in the secondary nearly one volt and 12,000 amperes.

There should be provision made by suitable switches to cut off the current from the pièces which are welded when the weld is known to be complete. This could be done, of course, by breaking the circuit of the secondary coil itself at the proper moment, but it is evident that for such large currents the switch would have to be very massive. Equally good results are obtained by cutting off the primary current, or by breaking the circuit of the dynamo.

To make an electric weld the pieces are rubbed bright near the ends to be joined so as to make good contact with the clamps by which the current enters; they are then placed in the clamps with their ends abutted in the free space between the clamps. The ends are of course clean, so as to form good contact, after which in most cases a little powdered borax is applied to the joint to act as a flux, or if the metal be of low melting point, as tin or lead, a little zinc chloride or tallow is applied.

It is of course best to have the clamps formed to fit the pieces, especially when they are of irregular outline; but for round or square work simple V grooves in the clamps suffice to hold the pieces in place and give the requisite contact.

When the pieces are in place and pressed together by the means provided, the current is turned on, and at once the ends of the bars heat at the junction, a slight yielding or approach of the pieces takes place, and before the operation could be described in words the work is done. Sometimes the joint is hammered to still further perfect and consolidate the weld.

Whether the electric current has any peculiar action in assisting the welding, I do not know, but am inclined to think that in some cases it has some such influence, although much the larger part of the work is the simple result of heat, I presume. One circumstance, however, arising out of the electrical properties of the metals dealt with may be noticed. This is the tendency to a uniform heating of the section of the bars abutted, as a consequence of the fact that cold metal is a better conductor than hot, and that, therefore, any cooler line of particles at once becomes the path for increased current, and is brought up in temperature to equality with the rest. I would call

attention to the fact that cheap water power can be utilized to furnish the energy necessary for use where such power is available and at a distance from its site. It would, indeed, be possible to follow out the details of this subject far beyond the limits of the present paper, but I will close by mentioning what may be regarded as curiosities of the art. One of these is the loud sound or snap due to the extra current, when the pieces in the clamps are not permitted to move together as the metal softens and a rupture of the secondary takes place between them, which rupture, although occurring in a circuit whose length is a very few feet, is attended with a loud snap, a bright flash, and forcible ejection of hot particles of metal, as if a fulminate had been fired between the pieces. I have had this action throw white-hot pieces of melted steel as large as a pea a distance of six or eight feet, and it is advisable to keep the eyes out of range.

We find our other curiosities in the work accomplished, such as small, broken twist drills mended in the twisted portion, a specimen of which I have, there being two joints in the twisted portion of the drill. Here, again, is a bar composed of steel, brass, and copper pieces joined end to end. Here is a lag screw, which was shortened by cutting out a piece between the square head and the screw portion, these two parts having been subsequently welded together, but in an incomplete way. Nevertheless, in turning the resulting screw into a block of hard wood by a wrench applied to the head it has twisted off an inch or two below the weld.

Lastly, I mention the case of a penknife which, having lost its blades by breakage close to the handle, has had new pieces of steel, subsequently ground into blades, welded onto the stumps of the old blades, which projected scarcely one-eighth of an inch from the handle, and the welding was done without removing the stumps from the tortoise-shell handle. Several other penknives have been similarly resuscitated, and I am pleased to say that in the one instance in which a blade was afterward accidentally broken it gave way at a distance from the weld.

After the reading of the paper, the operation of the apparatus was shown by welding pieces of various metals, such as iron, brass, and copper, a few seconds only being required for the operation.

MEETING 354.

Stellar Photography.

BY PROF. E. C. PICKERING.

The 354th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, December 23rd, at 8 P. M., Prof. C. R. Cross in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Prof. E. C. Pickering, director of Harvard College Observatory, who read a paper on "Stellar Photography."

Prof. PICKERING said: The qualifications required for an astronomer have varied greatly in different times. In the early days an astronomer was often a metaphysician who paid little attention to the stars. Later came the mathematical era. Then, with improved instruments, some mechanical skill was required. To use a large reflector, an astronomer must almost become a mechanical engineer. The spectroscope and photometer rendered a knowledge of physics essential. Now the question may be asked whether the astronomer of the future will not be a photographer.

Stellar photography is largely an American science. It originated in 1850 in a daguerreotype taken at the Harvard College Observatory, under the direction of Prof. William C. Bond. In 1857 Prof. George P. Bond again took up the subject under much more favorable conditions. His three classic memoirs on the subject render him the father of stellar photography. He showed that the position and brightness of the stars could be determined with great precision by this method. An elaborate study of the subject was made later by Mr. L. M. Rutherford, whose results unfortunately are mainly unpublished.

Dr. Gould, also, in South America, accumulated a large collection of photographs of star clusters and other objects of interest in the southern heavens. The work of Mr. De la Rue, of Dr. Draper, of Mr. Common, and of the brothers Henry was next described. The last named gentlemen have far surpassed their predecessors in the beauty of the maps they have constructed.

Most of the astronomers named above have devoted their attention mainly to the construction of maps or the determination of the position of the stars by photography. At Harvard an investigation has been going on for the past five years whose object is to apply photography to other branches of astronomy. (A series of photographs was projected on the screen to illustrate this proposition.)

A vast increase has taken place in the last few years in the sensitiveness of photographic plates. Even when the telescope is not driven by clock work, faint stars will mark their passage over the sensitive plate by leaving well defined lines or trails. These trails offer special advantages for measuring the brightness or position of the stars. Experiments showed that photography could be applied to a transit instrument, and promised important advantages.

In longitude work the great difficulty from personal equation would probably be entirely overcome.

By giving different exposures to the same object, as the nebula of Orion, the relative brightness of its different portions could be advantageously measured. During the past year, all the brighter stars north of 30° have been photographed at Harvard, in order to compare their photographic brightness. Several regions are photographed on each plate, the exposures being varied so that each star records the part of the sky in which it is situated.

One of the plates showed that the new star discovered in Orion during last December must have been much fainter six weeks before than when it was first noticed. In no other way can this fact be established.

One photograph showed an attempt to photograph a satellite of Jupiter during eclipse. Ten seconds was sufficient to produce a satisfactory image, and a large number of impressions could be obtained on a single plate by moving the telescope. A perfect automatic record was thus secured, in which any error in setting was incontrovertibly proved.

The most important investigation, however, has been with the spectra of the stars. Dr. Henry Draper was the first to obtain a satisfactory photograph of stellar spectra. His work was interrupted, in the midst, most unfortunately, by his death. Mrs. Draper has provided the means by which this work is now being carried on at Harvard as a memorial to Dr. Draper. Besides an eight-inch telescope with

which the work described above has been done, an eleven-inch telescope has been lent by Mrs. Draper, and mounted in the most approved manner. Four prisms, the largest eleven inches square, have been placed in front of the telescope, furnishing the finest piece of apparatus for the purpose ever constructed. All the instrumental work has been furnished by Alvan Clark & Sons. It is doubtful if it could otherwise have been obtained.

An assistant in the Observatory, Mr. Gerrish, devotes his entire time to this work. Three lady computers are engaged on the measurements and reduction of the photographs.

Three extensive investigations are now in progress. The first has secured photographs of the spectra of all stars visible to the naked eye in Cambridge. To avoid possible omissions, this work is to be repeated during the coming year. An exposure of five minutes is given to each spectrum, and a hundred or more are sometimes obtained upon a single plate. About six thousand spectra have already been measured and identified.

The second research relates to the fainter stars, each spectrum receiving an exposure of an hour.

The third investigation is conducted with the large telescope, and relates to the brighter stars.

The progressive improvements were shown, the length of the spectrum being successively increased from about a quarter of an inch to five inches. Large numbers of spectral lines appear in the later photographs, and a wide field is open to the study of the constitution of individual stars; not only is it possible thus to determine their chemical constitution, but probably some evidence will be furnished of the temperature and pressure to which they are subjected, and possibly their age. The motion of the stars towards or away from the earth may also be determined.

A vast field of work is open, and it is believed that the results will furnish the best possible memorial to one of the most skillful and ingenious astronomers that America has yet produced.

MEETING 355.

The Evolution of the Modern Yacht.

BY MR. EDWARD BURGESS.

The 355th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 20th, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the President introduced Mr. Edward Burgess, of Boston, who read a paper on "The Evolution of the Modern Yacht."

Mr. BURGESS said: The subject "The Evolution of the Modern Yacht" was chosen partly because it sounded well, but principally to call attention to the fact that in yachts, as in nearly everything else, the processes of evolution can be easily recognized. The gradual steps of advancement, from the dug-out to the Fortuna or Mayflower, may be traced without difficulty, and interesting parallelisms might be shown between yacht development and that of plants and animals. On the two sides of the Atlantic this development was taking place in widely diverging lines, in England the tendency being toward deep and narrow hulls, of which class the English cutters are the modern representatives, and in America skimming dishes, as they are called, were being developed. There were, a few years since, no connecting links between the two species. Here, again, a parallelism may be drawn with the natural development of any plant or animal species. Fifteen or twenty years ago, when the first cutter appeared in American waters, it seemed for a time that the sloops would be driven out of the field. It is human nature to find a novelty attractive. This is well illustrated in the fact that some of the stanchest advocates of the cutter are Americans, while many Englishmen plainly see the superiority of the sloop. But, for want of time to pursue this evolution, the speaker would confine himself to a history of sailing yachts, or, as they might be called, yachts of the nineteenth century. In the next century, if in yachting, as in other matters, the tendency is toward power and convenience, the poetry of sailing will give way to

the greater certainty of steam or electric yachting. Looking back but a comparatively few years, we find the beginning of the history of yachts and yachting. The first reference to the sport places its introduction in England in the last part of the seventeenth century. In 1800 the number of yachts in England was about fifty. The founding of the Royal Yacht Squadron in 1815, and the prestige thus given this form of amusement, greatly developed the taste for the sport, and from that time on the advancement was rapid, both in numbers and in quality. In 1850, the year before the arrival of the America, there were probably about 500 yachts owned in England. Down to this time the improvement had been in minor details. Some changes for the better had been made in rigging and ballasting, but no marked advancement had been made. The yachts then built were distinguished by their proportion of fore-body or bow to after-body or stern. Much theorizing on this subject was done, and, after the introduction of Scott Russell's wave theory, 3 to 2 was the generally accepted proportion. The Mosquito, and possibly one or two others, were built by this theory, but theory amounted to little in comparison with example, and the arrival of the America was needed to teach by example.

In America the year 1816 marks the introduction of yachting. At that time we were a more maritime nation than at present; that is, a larger proportion of the inhabitants were engaged in seafaring pursuits, and there was a much more universal appreciation of marine affairs. It is not at all strange, then, that the people of the United States should early develop an interest in yachting, or that the famous old town of Salem should be the home port of the first large American yacht. This was Cleopatra's barge, built for Captain George Crowninshield, in 1816, and launched late in the year, or in the first part of 1817. She was a 200-ton yacht, brigantine rigged. As soon as launched, her owner, accompanied by a jolly party, set sail for Europe. This is the first ocean cruise by a yacht on record. In England she naturally attracted much attention, crusing thence down to the Mediterranean. Captain Crowninshield, who was a very eccentric man, had her magnificently refitted at one of the southern ports of France, and then continued his cruise, a band of musicians accompanying him. At every port the yacht was an object of intense interest, and the log-book, which has been preserved, states that it was no uncommon occurrence to receive on board 5000 visitors in a

single day. The crowds were so great that on one occasion several people were pushed overboard. The peculiar painting and rigging of the craft doubtless increased this curiosity. On one side she had imitation ports painted, resembling a man-of-war, and at various parts of her hull fanciful pictures of fish and other animals appeared. Even the rigging partook of this variegated appearance, the ropes being laid of different colored cords. In spite of his eccentricities, Captain Crowninshield was a practical sailor, and the cruise ended happily. The Jefferson was a smaller yacht, also belonging to him, and became famous on account of bringing back the body of Captain Lawrence after the engagement of the Chesapeake.

In 1844 the New York Yacht Club was formed, the pioneer yacht club of the country. Commodore Stevens, assisted by Naval Architect George Steers, constructed many boats. Mr. Steers appreciated the need of a long bow, and put his theory into practice in the construction of the Maria, a sloop 95 feet long, or 10 feet longer than the Mayflower. The Maria became quite famous, and was very fast, but, on various accounts, she broke down easily, and thus lost many races. Among other peculiarities of construction, she had three centerboards, and her large spars were built barrel fashion, of staves and hoops. The Una was also one of the famous boats of the time. She is now schooner-rigged, and cruised last summer in eastern waters. Commodore Stevens was a very progressive man, and was not satisfied, so Steers built the America, which was a marvel of naval architecture. In 1851 she was sent to England, and, as is well known, captured the Queen's cup, coming in far ahead of all competitors. The result was naturally a great change in yacht building in England. During the winter following her visit, all English yacht yards were full of old yachts, having their bows lengthened after the America's style. Her proportions of bow to stern were 60 to 40. As a result, some yachts appeared during the summer which were almost entirely bow. After 1850 development progressed slowly in America, due first to the fact that we thought we knew it all, and secondly, because the development here was in an entirely different line. Already the English were tending toward the narrow, deep form, while our ideas favored the shallow sloop. There were several reasons for this divergence. First, the physical conditions of the cruising grounds were entirely different. Then the method of measuring for time allowance in England made

it advantageous to decrease the beam, and builders would increase the length while decreasing the beam. Mr. Burgess next gave a description, illustrating on the blackboard, of the action of the various forces of wind and wave acting on a moving yacht, showing that the deep boat can keel over to a much greater degree than can the more shallow sloop. Cross sections amidship were drawn, illustrating the position of the centers of gravity and buoyancy in the two classes. In England yacht designing became a scientific profession, while in the United States builders went by the rule of thumb methods. Nevertheless, the ocean race between the Henrietta and Vesta, in 1866, showed that we still had fast and seaworthy boats. In 1867 the Sappho was constructed in New York, and taken to England to sell, relying on the prestige which the America had given our yachts. After a defeat she returned to this country, and was given by Mr. Douglass, her purchaser, into the hands of Captain Bob Fish, a famous designer. Her beam was increased, and she was again sent to England, this time defeating her former antagonist, the Cambria. Not discouraged, the Cambria challenged again, and was again defeated, this time in American waters. The question is often asked why the defence of the cup is entrusted to one vessel, instead of allowing a fleet to compete. This is partially settled by the conditions under which the cup was given, and it would be manifestly unfair for one boat to compete with a fleet, some one of whose scattered members would be sure to obtain advantage of position, etc. The two Canadian yachts, Countess of Dufferin and Atalanta, were the next challengers. They were both easily vanquished, an American schooner taking care of the Countess, and the Mischief winning the other race.

During all this time advances had been going on in England, and development of the fast types, as the Genesta and Galatea, was alarming Americans. In England there are now over 2000 yachts, representing over £4,500,000. The United States probably equals that number, but the tonnage is considerably less.

Until the construction of the most recent yachts, almost the entire attention of Americans was directed toward the development of the schooner type. The Gracie was the only large sloop, and she was a somewhat patched up affair. There were a few cutters owned here, and some other fast boats, but it became evident that something must be done. The Priscilla in New York, and the Puritan in Boston,

resulted. In designing the Puritan, speed in light weather was not the object in view, but it was intended to make her a good all-around yacht. After the defeat of the Genesta by the Puritan, the challenge of the Galatea attracted, of course, much attention. She seemed to shows signs of greater speed, and we became alarmed again, and, as a second result, the Mayflower was built in Boston, and Ellsworth turned out the Atlantic at Brooklyn. The contests of these boats are fresh in the minds of all. In designing the Mayflower there were certain objects in view. The centers of gravity and buoyancy were both made lower, and a longer and easier bow constructed. There were various other minor changes, in the rigging, etc.

In closing, Mr. Burgess said that, while yachting needed no defence as a sport, its advantages were many. Besides serving to keep up the interest of Americans in American ship building, it has an important bearing in naval affairs. The Government has already made inquiries as to the number and speed of such yachts as could be used as despatch or small gunboats, and is having a census made of the available yachting sailors.

At the close of the lecture a large number of stereopticon views were shown, illustrating the essential differences in the sloop and cutter variety, and giving fine views of the various yachts as they have appeared in the races.

The meeting was adjourned after passing a vote of thanks to the speaker for his very interesting lecture.

MEETING 356.

The Use of the Freezing Process for Excavating in Soft Materials.

BY MR. CHARLES SOOYSMITH.

Experimental Comparison of Some Different Methods of Measuring the Flow of Water.

BY PROF. GEORGE F. SWAIN.

The 356th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 27th, Hon. J. A. Dresser in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Mr. Charles Sooysmith, of New York, who read a paper on "The Use of the Freezing Process for Excavating in Soft Materials."

Mr. SOOYSMITH said: The subject on which it is my privilege to address you has become known to engineers as the "Poetsch freezing process." The inventor was Mr. Hermann Poetsch, a German mining engineer of no particular note until he conceived and made a practical success of the method which bears his name. He had something to do with sinking a shaft near Ashersleben, Germany, to a vein of coal, where, after excavating about one hundred feet, a stratum of sand eighteen feet thick, overlying the coal, was encountered. It occurred to Mr. Poetsch that the great difficulty occasioned by the influx of water through the sand could be overcome by solidifying the entire mass by freezing. To accomplish this, he penetrated the sand to be excavated with large pipes sunk entirely through it and a foot or two into the underlying coal. These were placed in a circle at intervals of a meter and close to the periphery of the shaft. They were eight inches in diameter, and closed at the lower end. Inside each of these, extending nearly to the bottom, and open at its lower end, was a pipe but one inch in diameter. This system of pipes was so connected that a closed circulation could be produced down through the small pipes and up through the large ones. An ice machine, such as is used for cooling in breweries, making ice, etc., was set up near by and used to keep at a temperature below zero, F., a tank filled with a solution of chloride of magnesium, the freezing point of which is 40° below zero, F. The solution so cooled was circulated through the system of ground pipes described.

Thermometers were placed in pipes, sunk into the mass of the sand: the temperature of mass before the circulation of cold liquid was started was 51.8 F. The circulation was kept up and the temperature of the mass was rapidly lowered, and, at the point where the temperature was taken, the mass was frozen the third day after circulation had commenced. The freezing took place, of course, soonest about each pipe, beginning first near the bottom, where the inflowing solution was coldest, and extending outward in radial lines. The cylinders, or more correctly speaking, the frustums of cones about the pipes, finally met, thus forming a continuous frozen wall, inside of

which the material to be excavated was removed without any possible danger from caving in or inflow of water. The freezing, it was found, had taken place three feet into the coal, and to a distance six feet outside of the circle of pipes. The circulation of cold fluid was kept up until the excavation and walling up were complete.

This brief description of the first work suffices to explain the method in its simplest application. Other shafts were undertaken, and where much difficulty is encountered in passing through water-bearing strata, the process for this purpose is now coming into general use in Europe. For the shaft sunk in Germany, ice machines with a capacity of fifteen tons of ice per day, or, more scientifically speaking, capable of producing 3,150,000 thermal units, have been used. Of course, if we knew the specific and latent heat, and the conducting capacity of the material we wish to freeze, we could determine exactly the number of thermal units we should have to extract to solidify the mass. Taking a mass at a temperature of 25° C., consisting of sand and water in the proportion of 3 to 1, and assuming that no heat is supplied to the mass to be frozen, we would have to extract 116,802 thermal units per cubic yard to freeze the material. This would permit us, with an ice machine of 30 tons capacity daily, to freeze 54 cubic yards per day. And knowing the cubical contents of the mass we wish to freeze, we could in this way determine the time requisite for the freezing. In most cases, with the machines that would be used, the frozen wall would be formed in ten or fifteen days. As an actual fact, considerable cold is dissipated through the earth. It is very fortunate for us here that the soils of the earth and still water are comparatively poor conductors, the conductivity of water being about one ninety-fifth that of copper. It remains for some of our students who have the time to determine the rate at which the cold will be dissipated through different kinds of earth saturated with water,—and also to determine the strength of these when frozen, that, knowing the strain upon our wall, we may know how thick it must bé to surely resist this strain.

In sinking shafts, as the radial lines of conductivity from the pipes converge towards the center of the shaft, and there is no way for the cold to get out, so to speak, the entire mass inside of the circle of pipes freezes, while the desired ice wall is being frozen. This, of course, makes the excavation slow and expensive. Frozen sand and

water look like sandstone, and seem almost as hard. With pick and shovel, workmen in the bottom of a shaft will do very well if they average an inch in depth per hour. Of course the idea of thawing the interior mass at once suggests itself. Pipes for the circulation of heat could be inserted before freezing. My impression is, however, that blasting will prove the preferable method.

Probably the greatest service which this invention will render will be making practicable the construction of subaqueous tunnels, which could not otherwise be built.

In applying the freezing method to the construction of a tunnel there are a number of ways of arranging the ground pipes. Where the depth of water is not excessive, and where navigation and current in the stream do not bother, it would seem simplest and best to put pipes down from above in vertical or inclined positions, placing them in rows on either side of the proposed excavation. They can be incased in non-conductors of heat, except the portion about which it is desired to freeze. The circumstances where this manner would be practicable will not often occur, but we are more likely to meet with cases like that of the Hudson River tunnel, where the freezing pipes must be put in from the completed portion of the tunnel reaching forward beyond the heading. The problem of managing these pipes has been the occasion of a great deal of study, because the heading must be kept frozen, and pipes for freezing must be kept ahead of this. Then, too, the pipes must be so arranged that they will not interfere with putting in the permanent lining.

The result of my own study on the matter is to place the freezing pipes horizontal and parallel, and in a circle near the periphery of the tunnel, and somewhere from three to six feet apart, as experience shall teach may prove the best distance. The brick lining is kept along pretty close up to the excavation. Back at a convenient distance from the heading, in the finished portion of the tunnel, I would have a frame which can be readily moved forward at intervals. Against this frame will be worked the hydraulic jacks which will be employed to push the pipes forward. Occasional bricks can be temporarily left out of the lining to form offsets which can be used to hold the frame in place. Each of the large pipes would have a small pipe inside, extending nearly to the point where a diaphragm provided with a great number of small holes would form an obstruction to the circula-

tion. Another small pipe would pass the entire length of the larger one and through this diaphragm.

The ice machine may be located outside, and the cold solution brought through a well-wrapped pipe to the heading. Flexible connection could be made with the system of pipes so that the cold circulation can be maintained throughout the entire length of the pipe, excepting from the forward point back to the diaphragm. There will be no tendency whatever for the circulation to penetrate beyond the diaphragm. The object of thus limiting the circulation is to prevent possible freezing ahead of the pipe. When the excavation has progressed so that any one of the pipes should be pushed forward, the circulation of cold fluid in it is temporarily suspended, and for a few moments warm brine is circulated throughout the entire length of the pipe, being permitted to flow in through the longer small pipe. The result would be the thawing of the film about the large pipe. While thus loosened the pressure would be put on the hydraulic jack in which the large pipe terminates at the inner end, and by this means the pipe forced forward, say ten or fifteen feet. The circulation of the cold solution would then be resumed. The frozen mass would form a guide for the pipes.

In the case of the proposed subways under Broadway, New York city, the availability of this means of preventing with absolute certainty any lateral movement of the material about the foundation of the buildings ought to remove all fears of this danger in connection with that enterprise. Where necessary, in a case of this kind, a row of pipes could be sunk close to the curb line, and a frozen wall thus placed between the buildings and the street to be excavated.

This recalls another work of great importance that had to be done with extreme caution, which could have been accomplished with the greatest of security by the new method. I refer to the spreading of the foundations of the Washington monument at Washington. Since the monument has been completed, there has been considerable said about a stratum of sand which is said to exist below the foundation, and which it is feared may at some time be penetrated and the weight on the sand squeeze it out latterly. If this danger really exists, how easy it would be to freeze a wall about the monument, excavate through this stratum, and put in a permanent barrier to its exit. The freezing process removes also the chief difficulty in the construction

of subaqueous tunnels, by sinking them in sections from above, as has frequently been proposed. The chief difficulty in this latter method has always been to make the connection between the sections. To do so by freezing would be readily accomplished by providing the ends of the sections with a pipe running around them outside the tunnel space; then when it is desired to make the joint between two sections, after filling the space between them with mud, this latter could be frozen, thus forming a barrier to the influx of water while the permanent joint would be made. Another application has occurred to me in studying the difficulties that may have to be overcome in building a railroad tunnel between Canada and the United States, under the St. Clair River, where my firm is now driving a small experimental tunnel. Under the deepest portion of the river there is scarcely enough material intervening between the rock and the bottom of the river to leave a safe thickness overhead while the excavation is made. It may be necessary to provide what I may call an immense turtle-back, which could be lowered upon the bottom to serve as a temporary roof. To be effective it should be provided with low, sharp sides, and the entire under surface furnished with channels for the circulation of the cold fluid, so that when lowered upon the bottom of the river the thin roof that would have been dangerous could be converted into a frozen solid, which would perfectly protect the work underneath. Still another application occurs to me in connection with this work. The material at the center line of the proposed large tunnel is such that we anticipate no difficulty whatever in driving the six-foot heading which we are now commencing. Better than the turtle-back I have mentioned, it may be to use this trial tunnel as a means of freezing for a sufficient distance about it to permit the excavation of the large tunnel entirely in frozen material. To do this, a car with coils one or two hundred feet long, *i. e.*, the coil that length, not the pipe, in which the vehicle of cold could be circulated, could be introduced into the small tunnel and kept immediately in front of the excavation while this latter is made and the permanent lining put in. I believe that no difficulty would be found in freezing fifteen or even twenty feet radially out from this small tunnel by using means of ample capacity. Thus it will be seen that the construction of under-water tunnels, one of the most hazardous and expensive kinds of engineering, has a resource of incalculable value in this new method.

In the construction of deep and difficult bridge foundations, it is likely also to render great service. Where a foundation is to be obtained on a bed rock which is very unequal in elevation, and is overlaid by material hard to excavate on account of water, the freezing method is admirably adapted to cope with the difficulties encountered. Where such a pier is to be built in the water, a bottomless caisson or a coffer-dam would have to be first placed in position, and the freezing pipes put down through or inside the same. Such a coffer-dam may be made with less than the usual care, and earth of some kind filled in around the pipes and frozen. Another case in bridge construction where the process could be most advantageously used would be where it is desired to found a pier on bare rock where the water is of considerable depth. An open caisson could be sunk to the rock, being first provided around the bottom with a pipe through which a cold liquid could be circulated, after the caisson was settled to place, and sand dumped in about the space between the caisson and bed rock. When this should be frozen, it would perfectly shut off any entrance for the water, which could then be pumped out and the bed rock laid bare. The supreme advantage, however, of the process in bridge work will be in obtaining foundations where a trustworthy resting place is beyond the depth attainable by the pneumatic process, and there are many such places in this country where bridges are or will be badly needed. It has one disadvantage in comparison with the pneumatic process in any case where the two methods might otherwise be equally desirable, that is, the excavation has to be completed before any of the permanent work can be started. Whereas in obtaining a foundation by pneumatic process, the caisson itself becomes a part of the pier, and the masonry is laid on the caisson, while the latter is undermined and sunk. In other words, the pneumatic method would require less time. It has, however, the disadvantage that the caisson cannot always be sunk in the exact position desired, and the foundation is therefore generally superfluously large, adding in this way to the cost. By first excavating to the bed rock, the foundation could be built in the precise location and of the exact dimensions desired.

Where a ship has been sunk by collision, making it difficult to close the break, so that she could be pumped out and raised, the opening, however irregular, might be readily closed by freezing. To accom-

plish this, it would only be necessary to lower a coil of pipe into or about the opening, throwing something into the latter to impede the circulation of water, and then circulating the brine and freezing the opening fast. In salt water, it would, of course, take a very low temperature to accomplish the freezing. It would not be difficult to make an ice machine to produce an excessively low temperature. Those now made for commercial purposes can produce a working temperature of at least 15° or 20° below zero F.

An early application of the new process is likely to be made in sinking a shaft to a bed of sulphur discovered several years ago in Louisiana. This occurs at a depth nearly five hundred feet below the surface, and to reach it beds of sand have to be penetrated where the head of water in same is three hundred feet. An effort was made to pass through this, but failed, after an expenditure of, I believe, some two hundred thousand dollars. To sink this shaft, the pipes would either have to be put down the entire length at the start, or else resort would have to be had to some method similar to those mentioned in connection with tunnels; or it might be better to build the upper portion of the shaft so large that near the ends of the first set of pipes put in an offset could be made through which a second set could be inserted.

I have now mentioned the peculiar fitness of the Poetsch method for certain classes of work. The chief difficulty in applying it, where there is any difficulty, will be to insert the pipes properly. This difficulty is likely most often to arise from the presence of boulders or logs in the material to be penetrated. It is true this can be overcome by drilling, but it would be very expensive. There has not yet been sufficient experience obtained to enable us to determine the best sizes of ground pipes, and the maximum space we dare leave between them. Mr. Poetsch has continued to copy his first success, using eight-inch pipes placed about a meter apart. In some cases the pipes have not been sunk exactly as desired, leaving a space five or six feet between them at the bottom; still the frozen mass was continuous. The fact is that the freezing is due to cooling of the entire mass in the vicinity of the pipes, and it would seem more a question of total quantity of cold inserted and distance from the center of application of this than the distance of the point from any individual pipe.

Another possible difficulty that will occur only in rare cases is the

presence of considerable quantities of running water through the material to be frozen, that would thus be a vehicle to carry away the cold as fast as supplied. This difficulty is more likely to be encountered in sinking shafts to existing mines where pumping is in progress.

As regards cost of doing work by this process, if we except the expense of the possible difficulties just mentioned, we may estimate beforehand the cost of a proposed work with more accuracy than by any other method; and we may say the same with regard to the time required. This because of the certainty of removing the greatest contingency in such works, namely, that due to the influx of water or soft material. The enemy is converted to an ally and made to stand guard while the victory is won.

In under-water works accidents very often occur from the failure of machinery. Imagine, for instance, what would have happened to the pier at Havre-de-Grace had our pneumatic machinery failed, even for a few hours while we were holding the pier weighing millions of pounds on a cushion of air. With a frozen wall several feet above us, we would have been in safety while any conceivable accident to the ice machinery could be repaired, as it would have taken several days, or at least many hours, for dangerous thawing to occur. It has been customary in Europe, and will probably always be advisable, to keep the ice machine running until the permanent work is put in place.

Difficulty might be anticipated in putting in a brick or masonry wall close to the frozen material. As a fact no difficulty has been experienced in doing this.

The Old World has a more favorable field than the United States for the development of this process, because the coal fields have been more completely exhausted, and the time was ripe for the invention of a means of reaching the more inaccessible ones. Until three decades ago it was deemed practically impossible to bridge the Missouri, or the lower Mississippi, or to obtain adequate foundations in many other places where the difficulties have since been successfully overcome by the pneumatic process. And just as this has rendered easy and of common occurrence the execution of works not long ago regarded as impossible, so this freezing method seems destined to make a step forward of no less importance.

EXPERIMENTAL COMPARISON OF SOME DIFFERENT METHODS OF MEASURING THE FLOW OF WATER.

Prof. GEORGE F. SWAIN, of the Institute, was then introduced, and gave a description of the apparatus used by the students of the Institute for the gauging of water, with the results of some experiments carried out a few years ago.

Leaving out of consideration, he said, cases where the flow of water is gauged by actually measuring,— as in measuring-vessels, or by instruments such as some forms of water-meters,— the quantity of water passing in a given time, the ordinary method of gauging the flow is by finding the area of a certain cross-section of the current, together with the average velocity past that cross-section. But since in any current the velocity is different at different points, instruments must be used which will either enable us to determine the velocity at any given point, or the average velocity in a given vertical line, or in the entire cross-section.

The principal instruments for determining the velocity at any point in a flowing current were the double float and the current meter. The former consists of a large and heavy float, so weighted that it will just sink, suspended to a much smaller upper float, which remains upon the surface. By varying the length of the connecting line, the lower float may be suspended at any desired depth. The current meter consists of a wheel similar to an anemometer, set in motion by the current, and from the number of revolutions in a given time the velocity of the current is determined. Two styles of current meters were shown, in one of which the revolutions were counted electrically above the surface.

The average velocity in a vertical is determined by means of long weighted poles or tubes, which float upright, projecting several inches above the surface, and which give the average velocity in the vertical distance which they occupy. It may also be determined by moving a current meter uniformly from top to bottom; while the average velocity in an entire cross-section of rectangular shape may also be determined by moving the meter diagonally from top to bottom and back, thus crossing the stream, the meter taking a zig-zag course. When the meter is moved up and down in a vertical, the measurement is called a *vertical integration;* when diagonally up and down, a *diagonal inte-*

gration; and when a series of measurements at different points is made it is called a *point measurement.*

The methods of determining the quantity of water from the results of measurements with the instruments described were then explained by the speaker, and the results of some experiments which had been made by some of the students of the Institute in the tail-race of one of the mills at Lawrence were given. These experiments, the speaker stated, were not sufficiently extensive or numerous to enable definite conclusions to be drawn, but they gave certain indications which were of some interest. These were the following, applying, of course, only to the case of rectangular flumes in which the motion was quite irregular, as in the flume experimented upon, which was about 15 feet wide, 6 feet deep, and lined with plank, the velocity of the current being from 1½ to 3 feet per second.

First: That with tube measurements, if the tubes were well distributed across the width of the flume, a result practically correct might be obtained by simply taking the average of the velocities of the tubes, instead of plotting the observations and using a curve drawn between them in the most accurate manner. The result obtained by taking the average of the tube velocity was generally within one per cent of that obtained in the most accurate manner developed by Mr. Francis.

Second: That where measurements are made by the meter, taking vertical integrations in equidistant verticals, practically the same results are obtained whether these measurements are plotted and a curve drawn among the points obtained, or whether said points are connected by straight lines, or whether simply the average of the measurements is taken without graphical treatment.

Third: Assuming, as is no doubt true, that the most accurate method of finding the quantity from a series of measurements at certain points at different depths in a series of verticals is to multiply the velocity at each point by the small rectangle to which it may be considered to apply, and to add the results,— assuming this to be true, the ratio c was determined which the average velocity in the section bears to the average of the velocities at mid-depth. This ratio is supposed by Humphreys and Abbot, and by Ellis, to be practically constant for natural streams, but in the few experiments here made it was found quite variable, and although the average agreed well with the

ratio given by Ellis, the single observations differed widely. The results of the method by which simply the mid-depth velocity is measured would therefore seem unreliable in such flumes as the one experimented upon.

Fourth: The same seemed to be true regarding the method of calculation proposed by Gen. Abbot in the journal of the Franklin Institute, for 1873.

Fifth: Judging of the accuracy of a method by the agreement of successive measurements with each other, it appeared that of the methods with meters the diagonal integration gave the most uniform results (though with a possible difference between successive measurements of at least three per cent), the vertical integration coming next (with a possible error of apparently at least five per cent), and the point measurement next (with a possible difference of at least six per cent).

Sixth: Regarding the effect of the velocity with which the meter is moved in integrating, scarcely any effect was observed with the meter of Fteley and Stearns, at least up to velocities of motion of twenty or thirty per cent of the velocity of the current, any existing effect up to that rate being less than the differences between successive measurements under the same conditions. With the Ellis meter, however, as would be expected from its construction, the effect was apparent in a marked degree when the velocity of integration was as much as fifteen to twenty per cent of the velocity of the current. With the Ellis meter, under favorable conditions, the velocity of integration should be much smaller than with the Fteley and Stearns meter.

Seventh: Measurements with the Fteley and Stearns meter gave results uniformly smaller than those obtained by the tubes, by from one to three per cent. This was probably due to the fact that the meter cannot be accurately held in the plane of the cross-section.

Eighth: Measurements with the Ellis meter also gave results almost uniformly less than those with the tubes, by from one to seven per cent, a result which the speaker could not explain.

Ninth: The method of measurement by tubes, as perfected by Mr. James B. Francis, is by far the most accurate method in flumes such as the one experimented on.

In closing, the speaker again remarked that these results should only be looked upon as *indications*, since the number of experiments

was entirely too small to admit of definite conclusions. He hoped that more extended experiments in comparing different methods of measurement might be made by those who had facilities at hand for doing so.

A considerable discussion followed the two papers, after which the meeting adjourned with a vote of thanks to the speakers.

MEETING 357.

The Water Power of the United States.

BY MR. DWIGHT PORTER.

The 357th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, February 10th, at 8 P. M., Prof. George F. Swain in the chair.

After the reading of the minutes of the previous meeting, and the election of new members, the chairman introduced Mr. Dwight Porter of the Institute, who read a paper on "The Water Power of the United States."

MR. PORTER said: Until within twenty years water furnished the chief motive power for manufacturing in this country, steam not taking the lead long before 1870. Yet, notwithstanding the importance of this natural resource, very little has systematically been done directly to encourage its development. The National Government has, it is true, sought to foster manufacturing, and much has been done by local effort in various sections to aid in the establishment of new enterprises, with the result that an increased use of water power has been brought about. The increase, however, has been simply incidental, and even in those States possessing the most powerful and most suitable streams, it appears to have been a matter of indifference whether advantage were taken of these or whether coal were brought from distant points, provided there was a growth of manufacturing.

The slight interest taken in the development of the special re-

source here considered, is indicated by the lack of published information upon the subject. Geological and agricultural reports are common, but only one State, Maine, has made any effort worthy the name to set forth the advantages offered in the way of water power. In the Government census of 1870, statistics of power used in manufacturing appear for the first time. Ten years later the work was carried much farther, and an investigation was made, so far as time and means would allow, into the condition of the water power interests of the country, and into the number and location of important sites remaining undeveloped. The facts here presented and the conclusions drawn are based mainly upon the results of that inquiry, and would doubtless require to be modified somewhat to suit them to the present time.

The use of water power in this country began, as might be supposed, early in its colonial history. Lumber was wanted for building, and grain must be ground for food, and the operations thus involved gave the earliest employment to power. At first, wind power and the power of cattle and horses were frequently utilized, but water power soon became introduced, and was regarded with great favor because of the large amount of work that could be done with its aid. There were water mills in the vicinity of Boston before 1640, and within thirty or forty years from that time they had come into general use in the northern colonies. With the development of other branches of manufacturing the application of water power correspondingly increased. The manufacture of paper was introduced in Pennsylvania nearly two hundred years ago; and a century later in Rhode Island water power began to be utilized in the manufacture of cotton goods, and probably at about the same time in that of woolen cloth.

From the beginnings thus briefly traced the employment of water power in the various industries to which it is applied has steadily advanced. From time to time the most desirable sites, usually at first occupied by some unimportant saw or grist mill, have been taken possession of by water power and manufacturing companies, and famous industrial centers have here and there become established. What may be called the great powers, such as those at Lowell, Lawrence, Lewiston, Holyoke, Cohoes, and Minneapolis, have mostly been founded, or at least have begun their noteworthy history, since 1825, and several of them since 1850. At Rochester the Genesee River was called into service a century ago.

Passing now to an inquiry into the facilities offered by the different sections of the country for the development of water power, it is desirable to notice at the start the conditions that pertain to a good power. Technically, they are an ample and steady flow of water, a concentrated fall of sufficient amount, and suitable facilities for hydraulic improvements and the erection of mills. With plenty of water and fall, and a proper site for dam and mill, the useful application of the stream to manufacturing is easy, and the privilege may be considered technically good. But in order that it shall also have commercial value it must be within fair distance of supplies or markets, and command cheap and convenient transportation. In some one or more of these particulars a large number of water powers are deficient.

In volume and steadiness of flow the New England streams are specially well favored. A generous rainfall, well distributed through the seasons, and prevented from sinking beyond the reach of the streams by the hard rock strata underlying a shallow soil, assures a supply of water. Undue waste by evaporation is opposed by climate and by a wooded growth, which, in spite of the inroads of the lumbermen, still covers much of the surface. Extremes of flow are modified by the presence of numberless springs, swamps, ponds, and lakes, which in their natural state, as well as when controlled in reservoirs, hold back the waters they receive, which without them would rapidly drain away.

Studying other sections of country, we find that in the southern Atlantic and eastern Gulf States lakes are absent, but the heavy forest growth, the metamorphic underlying rocks in some districts, and a sandy soil in others, variously combine to give many of the streams a discharge approximating to that of the best Northern rivers. About the upper waters of the Mississippi the rainfall has decreased from the 40 or 45 inches of New England to from 25 to 35 inches, but it is favorably distributed through the year. Extensive forests cover portions of the region, and the country is dotted with a remarkable number of lakes, ranging in size from over a hundred square miles in a few cases down to the area of the smallest ponds. More than eight thousand of these lakes and ponds have been counted on the maps of Minnesota, Wisconsin, the upper peninsula of Michigan and eastern Dakota. Leaving the immediate valley of the Mississippi and entering the basin of the Missouri River, the rainfall diminishes from 40 inches at the

mouth to 20 inches in central Kansas, and even to 8 or 10 inches in Wyoming, and at many points five or six times as much is recorded in summer as in winter. Timber similarly decreases in amount, soon is confined to light fringes along the streams, and then disappears altogether until the mountains are reached. The dry westerly winds greadily suck up the moisture from the surface, and the streams, which in midsummer are swollen by heavy rains, rapidly afterward sink away to insignificant size, and even the Arkansas and Platte, the latter the largest tributary of the Missouri in point of area drained, have been known entirely to disappear in their sandy beds.

The second essential of a good power has been mentioned as the possession of concentrated fall. In the northern Atlantic States the hard granitic rocks compel the streams to accomplish much of their descent in sudden leaps and plunges, while farther south the rivers have been more successful in wearing down the surface material, and the fall is more uniform. In New England the fall obtained at the larger developed powers ranges in general from 30 to 60 feet. In New York State, owing to a different geological formation, concentrated falls of greater amount are not uncommon; as examples of which may be cited the abrupt pitch of 160 feet at the Niagara Falls, the descent of over 100 feet at Cohoes, and the many fine falls on the Hudson and Genesee Rivers. The latter stream on its way to Lake Ontario hurries down in a wonderful series of leaps,—three at Portage, covering an aggregate fall of 266 feet, and three more at Rochester, 60 miles below, amounting to 205 feet, with 60 or 70 feet of additional fall in rapids at each of these localities.

The streams of the southern Atlantic and eastern Gulf States have perhaps as large average slope as the more northerly rivers, but they accomplish this descent in rapids rather than in abrupt falls. Thus, at the great falls of the Catawba River, in South Carolina, there is a total descent of 100 feet, more or less, but it is scattered over a distance of a couple of miles. Similarly at the Narrows of the Yadkin, in the lower Coosa River, and in the Chattahoochee at Columbus, Georgia, are falls ranging in the different localities mentioned, from 80 to 120 feet, but in each case they are dispersed over several miles of river. The Tallassee Falls, in Alabama, are perhaps the finest, considering the volume of water at command, to be found anywhere in the section under consideration, the Tallapoosa River there dash-

ing down over rocky ledges in falls and rapids, and descending over 50 feet in 300 feet.

Adjacent to the upper waters of the Mississippi River and to Lakes Michigan and Superior, is a region of moderate elevation, the watershed lines rising as high as 1600 feet above sea level, in which the hard igneous rocks and Trenton limestone encountered by the streams have produced many rapids and sudden falls, and in which magnificent water powers are to be found. The lower Fox River, the St. Louis, and the Menominee, offer powers hardly to be surpassed by any in the United States. The St. Louis River enters Lake Superior at Duluth, after falling more than 450 feet in the last eleven miles of its course, and is one of the most valuable water power streams in the Northwest. At Minneapolis the Mississippi River, after running for hundreds of miles through the drift formation, suddenly cuts down through the rock strata, producing a power of grand proportions. A fall of about fifty feet is in use by the mills, and seventy feet are said to be available with proper improvements, corresponding with the water at command to 25,000 theoretical horse-power, even in the low stages of the river.

The prairie streams seldom show an abrupt fall, but run with even slope over beds largely of sand or loam, and the only fall obtained by improvements is commonly that due to the height of dam, not often exceeding eight or ten feet. On the Sioux River, in south-eastern Dakota, there are falls over ledges of quartzite at two or three points, those at Sioux Falls amounting to sixty or seventy feet, and being the most noted; but this river is exceptional among the prairie streams.

Mention must not be neglected of the power at Niagara Falls, where in recent years an attempt has been made, with considerable success, to employ a portion of the vast power of the Niagara River. The descent at the Falls is reckoned at 160 feet, and upon this basis the average theoretical power of the river is estimated to be at least 3,000,000 horse-power. These figures convey but little definite meaning to the mind, but some understanding of their significance can perhaps be gained when it is said that these falls represent an unfailing power at least fifty per cent greater than the combined power of all the water wheels in use in the United States.

On the Ohio River at Louisville, also, there is a fall of about

twenty-six feet at the most favorable stage of water; but it is so much diminished, and for so long a time, by high water, and any water power improvements must be so subordinated to the interests of navigation, that the employment of the power is hardly probable, though several plans to that end have been proposed.

The command of suitable conveniences for transportation is evidently essential to a good manufacturing site, and lack of these is the greatest bar to the development of many water powers. The value of those sites enjoying water communication has always been recognized, and such have been among the first to come into use. North of the Susquehanna there are but two streams of importance — the Penobscot and Presumpscot Rivers in Maine — on which there is still an undeveloped fall at the head of tide-water or of navigation. The narrow valleys, and rugged intervening country, of New England have forced the railroad lines there to the convenient vicinity of the streams; but in other portions of the country the railroads are found at considerable intervals from the courses of the streams, sometimes even traverse the divides, and in many cases cross the streams at a large angle, leaving intermediate sections without rail connections.

Having examined into the conditions necessary to the successful general development of water power, and noticed the degree in which those conditions are realized in different sections, it is in order to inquire into the extent to which utilization of the streams has actually taken place, and into the changes that have occurred within the period for which authentic data are at hand. That period does not reach back of 1870, at which time about 1,130,000 horse-power of water wheels was in use in this country. By 1880 there had been a net increase of between eight and nine per cent, or to 1,225,000 horse-power, the distribution of which it is interesting to notice. As would be expected, the main utilization is found to be upon the northern Atlantic slope.— the New England States, New York, and Pennsylvania together employing 61.4 per cent of the total power. New York takes the lead with 17.9 per cent, and Massachusetts is second with 11.3 per cent. The Connecticut River, with its tributaries, furnishes the greatest utilized power for a single river system; the Merrimac ranks next, and the Hudson third. In proportion to the extent of country drained, however, the Blackstone River does greater work than any other stream of equal size in the United States. A compari-

son of the Blackstone with the Missouri River is suggestive. The former drains but 460 square miles, and yet showed in 1880 for itself and its tributaries as large an amount of utilized power, within about one thousand horse-power, as the Missouri and all its tributaries, draining more than 500,000 square miles. Five great branches of manufacturing employ together eighty-five per cent of all the water power that is used. Flouring and grist mills use 38.4 per cent, saw-mills 22.7 per cent, cotton mills 12.1 per cent, paper mills 7.2 per cent, and woolen mills 4.4 per cent.

In the decade mentioned — 1870 – 1880 — there was a gain of about 95,000 horse-power in the amount of water power used in the country, and in analyzing this gain we are struck by the fact that while in a majority of the States, particularly in New England, New York, along the southern Atlantic slope, and in the upper basin of the Mississippi, there was a fair advance, yet in the three States of Pennsylvania, Ohio, and Virginia there was a noteworthy decrease, amounting for the three to 41,500 horse-power, three-quarters of it occurring in Pennsylvania. A further study will show that the increase in power used is to be accounted for in the cotton and paper mills of the Eastern States, and the flouring mills of the Northwest, while the great decline in Pennsylvania is among the saw mills. In the period under consideration there was in that State a marked decrease in the number of these mills (from 3700 to 2800), a correponding diminution in the product, and at the same time apparently an important substitution of steam for water power. Both in that section and in other parts of the country there is, undoubtedly, a growing tendency to the employment of portable steam saw mills, by reason both of their convenience and the cheapness with which they may be run, being fed entirely from waste.

The question of steam as a successful rival of water here forces itself upon the attention. It was only about a hundred years ago that steam came first to be applied in this country to driving the machinery of saw and grist mills. By that time water power had become firmly established by the usage of a century and a half, and was not easily to be supplanted; and yet that in the lapse of time it has to a large extent been supplanted in general manufacturing cannot be denied. In 1870 steam power was employed to the extent of 1,216,000 horse-power, over which the brilliant gain of nearly eighty per cent, to

2,185,000 horse-power, had been made by 1880. In every important industry in which water power is largely employed, a relatively greater amount of steam power was in use at the end of the decade than at its beginning. The causes which have led to this result form an interesting study in themselves, but their discussion will not be attempted in this paper.

MEETING 358.

The Bessemerizing of Copper Mattes.

BY DR. E. D. PETERS, JR.

The 358th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, February 24th, President Walker in the chair.

After the reading of the minutes of the previous meeting, the President introduced Dr. E. D. Peters, Jr., of Walpole, who spoke on the "Bessemerizing of Copper Mattes."

Dr. PETERS said: Despite the technicality of my subject, the process that I am about to describe has a claim to the attention of the general public as being a close counterpart of the steel Bessemer process which has so entirely revolutionized the iron industry.

But before you can at all appreciate the advantages possessed by this new method of treating copper ores, it is absolutely necessary that you should have a tolerably clear idea of the ordinary methods in use all over the world.

[Here the speaker gave a brief description of the ordinary furnace processes used in smelting copper ores, following the metal to the stage of blister-copper, which is the same product as that derived from the Bessemerizing method.]

Having now some idea of the long and complicated operations required to produce metallic copper from its sulphide ores, you can better appreciate the rapidity and simplicity of the new method.

I will not go into the history of this invention. Many noted metallurgists have had a strong faith in the possibility of applying the

same process to copper mattes that has been so successful in the manufacture of steel, and some have approached a successful termination. But I think no candid person can dispute me when I say it was reserved for M. Pièrre Manhès to make the Bessemerizing of copper mattes a metallurgical and commercial success in his works in France, whence it was brought to this country by the president of the Parrot Copper Company, and is yet successfully practiced in their works at Butte City, Montana. My own part in the matter was simply to build that portion of the smelting plant to treat the copper ores, and produce them in the shape of a matte (a fused sulphide of copper and iron) ready for the Bessemer process. This latter portion of the plant was built and conducted by pupils of M. Manhès, and I simply describe what I saw as a spectator.

The results of blowing a column of air through a vessel of molten iron are much simpler than when copper matte is substituted therefor. In the first instance we have a metal already ninety-five per cent fine or over, and containing only a few fractional percentages of impurities, such as C, Si, S, P, etc., most of which are also volatile. Therefore, little slag is formed, and when the operation is completed the volume of metal has sunk but little. But when air is blown through a copper matte of average grade, say thirty per cent, we have some seventy per cent of impurities to remove, one-half of which is iron and non-volatile. This encumbers the surface of the bath with enormous quantities of sticky, tenacious slag, consisting of subsilicate of iron, and when the blowing is finished we have left only some six hundred pounds of metallic copper, an amount too small to manipulate. [It should be understood that practical reasons have thus far limited a converter charge to two thousand pounds of matte.]

A still more important difference between iron and matte is that the latter is not a homogeneous substance; or rather does not remain so after the operation has proceeded so far as to oxidize all the iron and a portion of the sulphur present, so that the molten charge is a pure subsulphide of copper. It will be readily seen that as each additional particle of sulphur is volatilized, a particle of metallic copper is set free and sinks to the bottom of the converter, where it is met by the blast and so churned about and driven through the matte and slag that it is impossible to attain a clean metallic product.

This difficulty has been ingeniously conquered by M. Manhès by

placing the tuyères in a horizontal circle, two inches above the bottom of the converter, so that an opportunity is given for the metallic copper to collect in an undisturbed pool, below the influence of the blast, which still continues its oxidizing duties until the last particle of sulphide is decomposed, and the metal just reaches the level of the tuyères, when it is poured into moulds.

This horizontal placing of the tuyères was virtually the key to success, and after enumerating these few modifications there remains but little to describe to those familar with the genuine Bessemer process.

The difficulties arising when treating low-grade mattes, from the excessive formation of slag and the minute volume of the metallic product, are simply met by dividing the operation into two stages.

Assuming a twenty per cent matte to be under treatment; it is melted in a small cupola and run into the converter, where it is blown until its grade is increased to about sixty-five per cent, the slag being poured off once during the blowing, if it threatens to become troublesome.

When the charge has become nearly a pure subsulphide of copper (sixty-five to seventy per cent), the converter is turned down, and its entire contents poured into a large iron kettle on wheels. The slag, which forms a cake on top, and contains one or two per cent of copper, makes a most welcome flux for the ore smelting, while the cone of rich matte is laid one side till 20 or 30 tons accumulate, when it is remelted in a cupola, again run into the converter, and blown till it becomes blister-copper,— ninety-six to ninety-nine per cent.

An ordinary "blow" takes from twenty to forty minutes, so that allowing for changes, delays, etc., 25 to 30 blows of 2000 pounds each are made in twenty-four hours.

The converters are, of course, very much smaller and lighter than those used in steel manufacture, which hold 6 to 10 tons, and are lined with crushed quartz, to which is added just sufficient plastic fire-clay to make it hold together. After putting in a bottom several inches thick, an ordinary oil barrel is placed erect upon it, and the mixture rammed about this pattern, thinning out to almost nothing at the throat.

A battery of converters consists of three, of which one is in use, one undergoing repairs, and the third drying, ready for use.

When the operation is divided into two stages, as explained above, five converters are found sufficient for the purpose.

When the product of the blowing is an enriched matte, no extraneous fuel is needed to keep the converter at the proper temperature; but in running for blister-copper, the vessel gradually cools, until after the third or fourth blow it is found necessary to throw some 25 pounds of coke into the empty converter, which, being burned by a light blast, soon restores the lost heat.

This is not the place to go into questions of comparative cost, but it is evident to the meanest capacity that a great saving in plant and a great simplifying of operations must arise from the adoption of such a short cut to metallic copper. On the other hand, a constant large supply of matte is necessary to keep the plant properly at work, and a staff of highly trained workmen must be kept under regular pay.

The most evident saving is that of fuel, so that the economy of the new process is most marked where the price of fuel is the highest.

Under present conditions, one would hardly think of adopting it where coal was cheap and good, though it is quite within the bounds of possibility that, by greatly enlarging the converters and substituting machinery for man power in the manipulation of the same, the improved Bessemer operation may eventually be found the most economical under all conditions.

Since the electrolytic methods for the treatment of argentiferous blister-copper have become commercially successful, the field for the introduction of M. Manhès invention has been considerably enlarged; for now it is feasible to adopt his method on silver and gold bearing copper ores, and, by concentrating the precious metals in the blister-copper, obtain a product that can be separated with economy, whereas formerly it was necessary to separate the silver from the copper while in the condition of a matte, thus producing residues that could not be treated by Bessemerizing.

Another advantage gained by the employment of this process is the more or less perfect elimination of arsenic and antimony from the matte treated. M. Manhès claims that the elimination of these metalloids is perfect, no matter how great their quantity; but without expressing any opinion on such a very strong claim, I can testify that a blister-copper absolutely free from arsenic, and of most excellent quality, is produced without difficulty from matte containing enough

of these impurities to seriously impair the quality of the refined copper made from it by ordinary methods.

The future of the Bessemerizing process depends largely upon the policy of those who claim to control it in this country. At present, it is only used at the Parrot company's works in Montana; but we are informed that great improvements have been made, and it is probable that before long efforts will be made to introduce it at other points, where expensive fuel and low-grade sulphide ores demand something cheaper than the ordinary methods.

Prof. T. Egleston has published a paper in *The Columbia College Quarterly Magazine*, giving about all details that are yet known regarding the practical working of this process.

The meeting closed with a vote of thanks to the speaker.

MEETING 359.

Coal Mining.

BY MR. STUART M. BUCK.

The 359th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 10th, Mr. H. M. Howe in the chair.

After the reading of the minutes of the previous meeting, the chairman introduced Mr. Stuart M. Buck, of West Virginia, who read a paper on "Coal Mining; with a review of the more recent experiments on the action of dust in colliery explosions."

Mr. BUCK first described the different kinds of coal, giving their chemical composition, physical properties, etc. He then took up the general system of working coal mines, illustrated by blackboard sketches. The entries to the mine are driven in pairs for the sake of ventilation, and they are usually from eight to twelve feet in width, and separated by pillars of solid coal about 30 feet thick. These pillars are broken through by narrow cross-cuts, at intervals of from 100 to 150 feet (the old break-throughs being closed as soon as new ones

are made, so as to keep the current close to the working places of the miners). Branch entries similar to the above are turned off at intervals, and from these again the rooms in which the greater part of the coal is won. Rooms are usually 20 to 30 feet in width, narrow at the mouth, but soon widened. They are about 300 feet in length, and are separated from each other by pillars of coal 15 to 20 feet thick, left standing to support the roof. Whenever any section of the mine is exhausted it is customary to mine out the pillars, beginning with those farthest from the entrance. Another system, called the Longwall work advancing, is sometimes used, where the miner, after getting fairly away from the bottom of the shaft, works out the whole body of the coal, leaving no pillars of coal, but building protecting walls with broken rock and slate along the sides of the roadway, and allowing the roof of the mine to settle on these walls, and to fill up spaces from which the coal has been removed.

If the coal is very soft, only a pick is required to loosen it, but in anthracite mines the pick is little used, the coal being blasted like so much rock. In the majority of bituminous mines, however, it is first necessary to make an undercut three or four feet deep. This is the most difficult of the miner's work, but it is necessary in order to give the powder a chance to act without shattering the coal unnecessarily. Then holes are drilled so as to place the charge of powder close to the roof and over the back of the cut. Coal-cutting machines, driven by compressed air, are now successfully used in many places for making the undercut.

Many of the difficulties and dangers of coal mining have been overcome; but, in spite of all improvements and safety contrivances, many still remain, and among them are roof-falls and fire-damp. Roof-falls are far more dangerous than gas explosions; but, coming singly and at scattered mines, they do not attract the same attention, and are only noticed in tables of statistics.

Fire-damp is a mixture of gases, varying at different places, and consisting principally of light carburetted hydrogen, or marsh gas, but also containing some carbonic acid, nitrogen, and other hydro-carbon compounds, with a specific gravity of only fifty-five per cent as compared with atmospheric air. It is generally without color, taste, or odor, and burns when pure with a yellow flame. It is not poisonous, and can be breathed when forming one-third of the air. On account

of the low specific gravity, it collects most readily near the roof of the mine, but speedily mixes with the air through diffusion. It is detected when in small amount by its effect on the flame of the safety lamp; two per cent is the smallest amount that can be detected with an ordinary lamp, the flame increasing in length and size with the amount of gas. The mixture first becomes explosive when there is six and two-thirds per cent of gas; it is most explosive at ten per cent; and at fifteen and a half per cent it ceases to be explosive and extinguishes the light.

The peculiar principle of the safety lamp was discovered in 1815 by George Stephenson, and also by Sir Humphrey Davy. This principle is that the encasing wire gauze so far cools the burning gas within that the flame does not communicate with the surrounding explosive mixture. This is true so long as every lamp is in perfect condition and there is no sudden movement of the air or carelessness.

In order to dilute the percentage of fire-damp to the least possible amount, centrifugal fans have been used, giving a ventilating current of 150,000 up to 250,000 cubic feet of air per minute.

Fire-damp is not found in all mines, and many parts of our own country have so far been considered entirely free from it. Miners generally contend that drift openings are not liable to fire-damp, but this is not so, and with each year's more extended workings the danger increases.

Loose coal gives off gas constantly, so that the more coal is loosened from day to day the greater the danger. If the mine is allowed to stand a few days, the percentage of fire-damp decreases. There is also an increase of fire-damp with any lowering of the atmospheric pressure. In fiery mines there is a liability to sudden outbursts of gas called blowers, and against these it is hard to take precautions. Since the phenomena of natural gas have been studied these outbursts seem less strange, though perhaps no better understood. It is interesting in this connection to note the experience of the Prussian fire-damp commissioners, that the mine gas proves most abundant when the coal is folded on an anticlinal axis not reaching the surface and accompanied by a porous sandstone overlaid by clay slate. This is especially true where the drainage has removed the water and increased the porosity of the sandstone.

The influence of coal dust in colliery explosions was first noticed

by Lyell and Faraday in 1884, and it was recognized as increasing the force of gas explosions. In 1876 Galloway showed by experiment that, while more than six per cent of gas alone was required to make an inflammable mixture with air, less than one per cent of gas was required in the presence of fine coal dust.

Further experiments between 1879 and 1881 led Galloway to believe that an explosion produced by a local occurrence of fire-damp might be indefinitely extended in an atmosphere loaded with coal dust.

In 1876 a paper was read before the North of England Institute of Mining Engineers, by Messrs. Hall and Clark, showing, as a result of their experiments, that the presence of fire-damp was not necessary, but that a blown-out shot in the presence of fine coal dust would cause an explosion. In coal mining a blown-out shot is one where the tamping is blown out by powder without any decided action on the coal, and the effect is much the same as though a cannon were fired in the same position. The force of the powder is expended in projecting the current into the air of the mine, and stirs up any dust that may be present. At the same time it is thought by many that the partial vacuum succeeding a blown-out shot tends to draw the gas from the coal more rapidly than would otherwise be the case.

In the course of the investigations following the Seaham colliery explosion in England in 1880, it was further shown that fine dust, which in itself was entirely incombustible, had a distinct effect in explosions, and made dangerous a low percentage of gas, which of itself would be quite harmless.

In 1883 it was generally admitted by all who had given special attention to the subject that all gas explosions were more violent in the presence of fine coal dust, and that dust would render explosive a mixture of air containing two per cent, or possibly as low as one per cent of fire-damp. But Mr. Galloway was looked upon as an enthusiast, if not a crank, and his claim that coal dust alone could lead to an explosion, in the absence of gas, found little credit. About the same time a Government commission was appointed in France to examine the same subject, and they reported that dust in the absence of gas was not a cause of serious danger.

Partly owing to Mr. Galloway's paper, and partly owing to the renewed attention called to the subject by certain flour-mill explosions, the matter was taken up again in Prussia, and intrusted for

investigation to one section of the Prussian fire-damp commission, which first met in June, 1881, and made its final report in November, 1885. The experiments were made in a gallery of elliptical form, 5 feet 7 inches by 3 feet 11 inches, and 167 feet long, so arranged as to give a chance for observation without danger to life or limb. The speaker gave a detailed example of the manner of conducting these experiments, and the results of a number of the experiments.

Over four hundred such experiments were carried out with the greatest care, and the results were well established.

The most important deductions are as follows: —

First: That with certain classes of coal dust an actual explosion, extending beyond the limit of the dust deposit, may be caused by a blown-out shot, even when fire-damp is entirely absent.

Second: That while the finest dust is usually the most dangerous, the chemical composition of the coal is more important, and that a volatile percentage of from sixteen to twenty-four is the most dangerous.

Third: That a three per cent gas mixture, in the *absence* of scattered dust, causes *no danger* in case of a blown-out shot, even though tamped with the most dangerous dust, and that a six per cent mixture is required for actual *explosion.*

Fourth: That dust in pure air cannot spread a flame from a lamp alone; that fire-damp up to three and three-quarters per cent, without dust, only lengthens a lamp flame; that at four per cent the flame begins to slowly spread, at the rate of one foot per second, and that at six per cent the speed is six feet per second, and incipient explosions take place. Let dust be present, and explosions may be started by an open lamp with only five per cent of gas.

Fifth: That for insuring safety, the dust must be wet down with fifty per cent of its weight of water,— not simply moistened,— and that this must be done for a space of fifty feet back from the face of the coal.

Sixth: That the Davy lamp as a test for gas is only to be trusted from three per cent up; but that the Pieler lamp can be relied on for detecting one-half per cent of gas, and for estimating mixtures of from one to three per cent.

Seventh: That the time required for the full, natural diffusion of fire-damp in a mine gallery of ordinary size is from three to four hours.

These are the principal points settled by the Prussian commission, and it is of interest to us to consider if the subject is to be looked at as practical or only as theoretical. In other words, have we ever had, or are we likely to have, a coal-dust explosion in this country?

The explosion at the Pocahontas mine, which occurred March 13, 1884, was by many persons regarded as a dust explosion, even at that time, and as more light has been thrown on the subject, that theory has gradually received more favor.

Mr. Buck then described the Pocahontas mine, giving a full description of the effects of the explosion.

As a result of the examination by experts the opinion was expressed that the explosion was due mainly to dust. It could not be determined whether its initial cause was a blast or the accidental ignition of a small quantity of fire-damp, but it was believed that the explosion was due either to dust alone, or to dust quickened by an admixture of fire-damp too slight for detection by ordinary means. The speaker said that no gas had ever been noticed in the mine before the explosion except once; that no gas was found on re-opening the mine; and none since, so far as known.

A vote of thanks to the speaker brought the meeting to a close.

MEETING 360.

The Source of Business Profits.

BY PRESIDENT FRANCIS A. WALKER.

The 360th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 24th, at 8 P. M., President Walker in the chair.

After the reading of the minutes of the last meeting and the election of new members, the President announced the subject of the evening to be "The Source of Business Profits."

After referring to the criticisms of Prof. Sidgwick, the speaker proceeded to explain his theory of the source of business profits.

Prest. WALKER said: It is not to be disputed that, if this theory be a correct one, it supplies just what was lacking, and yields, in conjunction with well-approved theories of rent, interest, and wages, a complete and consistent body of doctrine regarding the distribution of wealth. It is not to be disputed that we have, in this view of business profits, the key-stone to bind together the other members of the arch in a symmetrical whole, spanning the entire field of distribution. But it is competent to anyone to dispute the correctness of this theory regarding the employer's proper share of the produce, and time has not yet been given for such a discussion of the doctrine as shall decide whether it is to be approved or rejected by the body of economists. The first stages of the discussion have certainly not been more unfavorable towards the view presented than was reasonably to be anticipated.

We shall best approach our present subject by inquiring what would be the share of the produce going to the employer, as such, irrespective of the proper interest on capital (of which the employer himself may or may not be the owner), in case the body of employers constituted a distinct class, either naturally or artificially defined, all of whose members were equal among themselves in the point of business abilities and business opportunities. Let our hypothesis be clearly understood. We assume, first, that there is in a given community a number of employers, more or fewer, who alone are, by law or by custom, permitted to do the business of that community in banking, in manufacturing, in trade, in transportation, or else who are so exceptionally gifted and endowed by nature for performing this industrial function that no one not of that class would aspire thereto or would be conceded any credit or patronage should he so aspire. Secondly, we assume that neither in point of ability nor of opportunity has any one member of this class an advantage as against another, each being the precise economic equivalent of every other,—all being, we might say, exact copies of the type taken, whether that should involve a very high or a comparatively low order of industrial power.

Now, in the case assumed, what would be true of business profits, the remuneration of the employing class? I answer that, if the members of this class were few, they might conceivably effect a combina-

tion among themselves; and, through possessing a natural or artificial monopoly of a force absolutely indispensable to the conduct of industry, they might fix a standard for their own remuneration, which should be the price for which they would consent to carry on the business of that community. If, however, the community were a large one, and if the business class, as we have defined it, were numerous, such a combination to determine profits would be impracticable. Rivalry, jealousy, greed, personal quarrels, pique, or suspicion of foul play would soon break up the most elaborate scheme; and the members of the business class would begin to compete with each other. From the moment competition set in, it would find no natural stopping place until it had reduced profits to that minimum which, for the purposes of the present discussion, we call *nil*.

What, in the case supposed, would be the minimum of profits? I answer: This would depend upon an element not yet introduced into our problem. The ultimate minimum would be the amount of profits necessary to keep alive a sufficient number of the employing class to transact the necessary business of the community. Whether, however, competition would force profits down to this low point would depend on the ability or inability of the members of the employing class to escape into the laboring class. We have supposed that laborers could not become employers; but it does not follow that employers might not become laborers and earn the wages of laborers, in case their remuneration as employers should be reduced by competition below the current rate of wages. If we supplement our hypothesis by assuming that the body of employers have such an industrial resort or escape, we should then have the minimum rate of profits determined by the current rate of wages; and it would come about that an employer would receive a remuneration equal to that which he might be able to earn as a laborer. Less than this he would not receive, because he would prefer to serve in the other capacity. More than this he would not receive, because the unceasing competition of his fellows would wrest from him every fraction of any excess that might remain. It would not matter in the least that the services which the employer rendered were, in his view or anybody else's view, of a more highly intellectual character or morally more deserving than those rendered by the laborers. We are accustomed to the spectacle of work involving more than ordinary moral and intellectual qualifica-

tions, and even work absolutely indispensable to the life and health of others, compensated at rates far lower than those paid for some mere knack or skill, or physical adaptation to the rendering of a service demanded only by a whim or fancy of the consumer, which may even be positively deleterious to health or character. It is all a question of supply and demand; and, in the case assumed, the remuneration of the employing class, whatever their moral or intellectual qualifications, as compared with those of the rest of the community, would infallibly be reduced through the normal effect of competition to a level with the remuneration of the laboring class. It would then become a matter of economic indifference whether any man served the community as laborer or as employer. In this event, profits would become *nil;* that is, there would be no profits as distinguished from or preferred to wages.

Leaving now our imaginary society and returning to the actual world of industry, do we find anything corresponding to the result we have last reached? Do we find employers of labor earning profits which are no greater than the wages of labor? I answer that in every large community there are many such employers; and in every branch of business in a large community there are some such employers,— men who, by their conduct of the industrial enterprises of which they have come, no matter how, into control, realize no remuneration greater than that received by the laboring class.

Indeed, we may take a step beyond, and say that in every large community there are many employers, and in every branch of business some employers, whose conduct of business results only in loss. What with the initial investment of the employer's own inherited or previously accumulated means; what with the loan of funds by friends or relatives; what with the discount of commercial paper, under more or less of uncertainty as to the financial standing of drawers or indorsers; what with credit given by dealers for materials or supplies, and in a less degree by laborers for their work rendered,— it happens not infrequently that men carry on large business, not only with no resulting profit, but an actual loss to themselves or to others.

Just above the grade of employers we have described are found many employers in every large community, and some in every branch of business, who realize, at best, but very moderate profits. Even at the end of a long career, these men are found to have accumulated

little or nothing. They have, indeed, lived more comfortably than the more favored of the wage-receivers; but for this they have paid a high price in perpetual anxiety concerning the state of the market, in frequent fears of commercial misfortune, and perhaps at times in much embarrassment and much humiliation. All things considered, their economic condition has been little, if any, superior to that of the better members of the hired class,—such as book-keepers, cashiers, clerks, superintendents, or overseers. Even if we threw out of account those who realize literally no profit at all, or sustain an actual loss, we should still have, in the grade of employers at present under consideration, a class whose profits might, for the purposes of the present discussion, be taken as *nil*.—amounting, that is, to little, if anything, more than the same persons might hope to receive in the employ of others, and that, too, with much less of mental pressure and nervous wear and tear. Taking our stand on this line, we see the body of employers, viewed with respect to the remuneration received for the conduct of business, rising upwards by insensible gradations, but through long distances, until we come to those rarely gifted masters of industry who are capable of managing the largest enterprises with uniform success, and who seem to turn everything they touch into gold. Looking at the better employers of whatever grade, whether the shrewd, strong, sensible, watchful men of business who achieve a decided success, or the sagacious, resolute, and daring spirits who are by all recognized as masters in their respective trades or avocations, or the men with a high genius for commercial combinations, with a great power over the minds and wills of others, and with an insight into the state of the market and the conditions of trade which approaches foresight, we note that they pay wages, as a rule, equal to those paid by employers who realize no profits or even sustain a loss; and that, indeed, if regularity of employment be taken, as it should be, into account, the employers of the former class pay really higher wages than the latter class. We note further that the successful men of business pay as high prices for materials and as high rates of interest for the use of capital, if the scale of their transactions and the greater security of payment be taken, as it should be, into account.

Whence, then, comes the surplus which is left in the hands of the higher grades of employers, after the payment of wages, the purchase of materials and supplies, the repair and renewal of machinery and

plant? I answer: This surplus, in the case of any employer, represents that which he is able to produce over and above what an employer of the lowest industrial grade can produce with equal amounts of labor and capital. In other words, this surplus is of his own creation, produced wholly by that business ability which raises him above and distinguishes him from the employers of what may be called the no-profits class.

This excess of produce has not, speaking broadly, been generated by any greater strain upon the nervous or muscular power. Indeed, it may as a rule be confidently stated that, in works controlled by men who have a high power of administration and a marked degree of executive ability, where everything goes smoothly and swiftly forward to its end, where emergencies are long foreseen, and unfavorable contingencies are carefully guarded against, where no steps have to be retraced, and where nothing ever comes out wrong end foremost, there is much less of nervous and muscular wear and tear than in works under inferior management. The excess of produce which we are contemplating comes from directing force to its proper object by the simplest and shortest ways; from saving all unnecessary waste of materials and machinery; from boldly incurring the expense — the often large expense — of improved processes and appliances, while closely scrutinizing outgo and practising a thousand petty economies in unessential matters; from meeting the demands of the market most aptly and instantly; and, lastly, from exercising a sound judgment as to the time of sale and the terms of payment. It is on account of the wide range among the employers of labor, in the matter of ability to meet these exacting conditions of business success, that we have the phenomenon in every community and in every trade, in whatever state of the market, of some employers realizing no profits at all, while others are making fair profits; others, again, large profits; others, still, colossal profits. Side by side, in the same business, with equal command of capital, with equal opportunities, one man is gradually sinking a fortune, while another is doubling or trebling his accumulations.

Assuming, for the present, the correctness of this view of the origin of profits, let us proceed to inquire how the employer's remuneration, thus determined, stands related, first, to the price of produce, and, secondly, to the wages of labor.

Well-approved principles of political economy will not allow us to question that in this view profits do not enter at all into the price of produce. The normal price of any kind of goods is determined by the cost of that last considerable portion of the supply which is produced at the greatest disadvantage. Wheat is raised on some farms at a cost of two shillings a bushel; but this wheat is not, therefore, sold at two shillings, nor does it even tend to be sold at that price. If the demand for wheat is so great as to require a portion of the supply to be raised and brought to market from soils so poor or from regions so distant as to involve a cost of six shillings, all the wheat in the market will be sold at that price: and those who produce it at a relative advantage will derive a profit which, as in this case issuing from land, we call rent.

Likewise the cost of maintaining the employers of the lowest industrial grade necessarily enters into the normal price of produce. But we have already noted that the remuneration or means of subsistence of this class of employers would, under full competition, not exceed the remuneration of the same persons if themselves employed by others; and profits not in excess of wages we have agreed to consider no profits at all. The cost of that portion of the necessary supply which is produced under the direction of employers of this class fixes the price of the whole supply; and those who produce at a relative advantage have left in their hands a surplus, after paying wages, interest, and rent, at rates equal, all things taken into account, to those which are paid by employers who realize no gain for themselves.

That profits are not obtained by deduction from wages is equally clear when we consider that the most successful employers pay as high wages as the employers who realize no profit. Indeed, as we saw, a preference, not always a slight preference, exists on the side of the more successful men of business, since the greater continuity of employment and the greater security of payment constitute a virtual addition to wages.

It will be seen that, in the view here presented of the origin and the measure of profits, this form of industrial remuneration is closely assimilated to rent. This I believe to be the true explanation of business profits. Under free and full competition, the successful employers of labor would earn a remuneration which would be exactly measured, in the case of each man, by the amount of wealth which he

could produce, with a given application of labor and capital, over and above what would be produced by employers of the lowest industrial, or no-profits, grade, making use of the same amounts of labor and capital, just as rent measures the surplus of the produce of the better lands over and above what would be produced by the same application of labor and capital to the least productive lands which contribute to the supply of the market, lands which themselves bear no rent.

If the view here presented be a correct one, it will appear that it is for the interest of the community, particularly of the wages class, that the conduct of industrial enterprises should be restricted to men of distinct, decided business ability. As, in rent, any lowering of the margin of cultivation, bringing into use lands of a smaller net productiveness, increases the cost of production of that last necessary portion of the supply which fixes the price of the whole crop, and does thereby enhance the proportion of the produce which goes to the land-holding class as rent, so in profits, we see that to commit the conduct of business to an inferior order of men, having, so to speak, smaller net productiveness in the use of labor and capital, is to enhance the cost of that last necessary portion of the supply which determines the price of the whole stock, and is thus to increase the share of the product of industry going to the employers of higher grades, as profits.

If this be correct, we see how mistaken is that opinion too often entertained by the wages class, which regards the successful employers of labor — men who realize large fortunes in manufactures or trade — as having in some way injured or robbed them, while extending to the less successful or altogether unsuccessful employers of labor a considerable degree of sympathy. So far as such sympathy springs from a natural kindness of feeling and a disposition to take the part of the unfortunate, it is right and commendable. So far, however, as it is of an economic origin, growing out of the belief that the employers of the higher class have made their large profits at the expense of their laborers, it is both mistaken and mischievous. The men who do business at the cost of the working classes are the men who do business poorly; first, for the reason that we have stated,— namely, that it is the lowest grade of business ability that determines the price of the produce; and, secondly, because incompetence in the conduct of business enterprises has much to do with bringing about those shocks to

credit, disturbances of production, and fluctuations of prices from which the community as a whole, but particularly the working classes, suffer so greatly. The first interest of the community is that business shall be well done,—done with energy, efficiency, and economy, done with prudence, judgment, and foresight. Anything which lowers the character of the business class in these respects works serious injury to all classes of producers, and especially to that class which is, in the nature of the case, under the greatest economic disadvantage at the start.

Many things tend to allow incompetent persons to force themselves into the control of business, and to maintain themselves there at the expense of the general community. "Protection," in my opinion, does this. The practice of "truck," or the payment of wages in kind, unquestionably has this effect, enabling men who could never earn a legitimate profit to extort a fraudulent profit from their hands. Slavery, of course, allowed and encouraged incompetence, shiftlessness, and wastefulness in the conduct of business; and it was quite as much the character of the employing class as the inferior quality of the chattel labor which brought about the wretched industrial results obtained under that system. Bad money is a fruitful cause of the downward extension of the employing class, lowering the margin of production in this respect, thereby enhancing the cost of that last necessary portion of the supply which determines the price of the whole, and thus increasing, uselessly, and to the loss of the community, the profits of the employing class. Another important class of causes which produce, in greater or less degree, the same mischievous result relate to the collection of debts and the penalties for commercial delinquency or insolvency. Whether it be shilly-shally laws respecting bankruptcy, or bad judicial machinery for the determination and enforcement of commercial obligations, or a dishonest or maudlin public sentiment regarding the unfortunate debtor, the effect is the same. Men who for the general good should be relentlessly thrown out of the conduct of business and remitted to subordinate positions in the industrial organization, are allowed to hang miserably on to their mistaken career. Finally, ignorance, inertness, and improvidence on the part of the working classes greatly increase the opportunities for incompetent men to crowd themselves into the control of labor and capital, and to conduct industrial enterprises at the cost of the general community.

Here, again, we see an occasion for labor to win a larger share of the produce without any injury to industry, and, indeed, directly through an improvement in the average quality of the industrial enterprises of the community. Here, again, we find an illustration of the principle that the economic condition of the laboring class is very largely put into their own hands, to deal with as they shall please, or rather as they shall will to do.

Such, in rude outline, is my view of business profits. We have here a theoretical determination and delimitation of the remuneration of the employing class, which is perfectly self-consistent and rational, and which, if approved by economic opinion as properly and fully accounting for the industrial facts with reference to which our hypothesis was constructed, gives us all that was lacking towards the theoretical determination of wages.

First: Rent is to be deducted from the produce of industry, its amount to be determined by the Ricardian formula, with more or less of remission, in fact, from landlord to tenant, under the influence of custom or kindly feeling, as these causes may be found to operate.

Secondly: Interest is to be deducted as the remuneration for the use of capital, its amount being determined by the relation of supply and demand, but always tending, through the operation of a natural law on which all economists, from Adam Smith down, have delighted to dwell, towards a minimum,— the minimum, in the case of interest, being that rate which will induce the possessors of wealth to refrain from consuming it for the immediate gratification of their tastes and appetites, and to save and store it up to the extent of making good the waste and wear of the existing stock of capital and of answering the demands for the enlargement of that stock to meet new occasions for productive expenditure. This condition may imply, in one state of society, an interest rate of eight per cent; in another, of five; in another, of three. But, whenever the rate is eight per cent, it continually tends to become five; and, whenever it is five, it continually tends to become three, inasmuch as the occasions for an increased expenditure of wealth for productive uses are certain to be soon transcended, at any given rate of interest, by the rapid accumulations of capital, which go forward by geometrical progression.

Thirdly: There is to be deducted profits, the remuneration of the employing class, determined as we have seen, by principles closely

analogous to those which determine rent. In this view, profits constitute no part of the price of goods, and are obtained through no deduction from the wages of labor. On the contrary, they are the creation of those who receive them, each employer's profits representing that which he has produced over and above what the employers of the lowest industrial grade have been able to produce with equal amounts of labor and capital.

After these three successive deductions, there remains wages. This is the residual share of the product of industry,—residual in this sense, that it is enhanced by every cause which increases the product of industry without giving to any one of the other three parties to production a claim to an increased remuneration, under the operation of the principles already stated; residual in the sense that, even if any one or all of the other parties to production become so engaged in any given increase of the product as to become entitled to an enhanced share in its distribution, their shares still remain subject to determination by positive reasons, while wages receive the benefit of all that is left over after the other claimants are satisfied.

Now, granting the correctness of the analysis here offered, it is demonstrable that the product may be increased without enhancing the share of all or of any of the other parties to distribution; and, even when the other shares are enhanced, it is possible and even probable that, on the assumption of perfect competition, the increase of product resulting from the introduction of any new force into industry will be greater than the sum of the increments by which rent, interest, and profits shall have been enhanced. If this be so, then the wages class receive a benefit from any increase of the product of industry corresponding to that derived by the residuary legatee whenever the total value of the estate concerned is ascertained to have been, or by some unanticipated cause becomes, larger than was in contemplation of the testator when the amounts of several specific bequests were determined upon.

Thus to take the simplest possible case, let us say that the line *ax*

a———b———c———d——————————x.........y

represents the amount of the production of a given community. Of this total, *ax*, let *ab* represent the share going to the land-holding class as rent; *bc* the remuneration of the capitalist class, under the name

of interest; dx the portion of the produce paid in wages; and, by consequence, cd the part retained by the employing class as profits. Let it now be supposed that an instantaneous improvement takes place in the industrial quality of the laboring class, by which they become so much more careful and painstaking, more adroit and alert, more observant and dexterous, as to effect a saving in the materials used in each and every stage of production, with a resulting increase of ten per cent in the finished product over what had been accomplished by more wasteful, clumsy, heedless operatives. This assumption is certainly not an unreasonable one, as regards the extent of the possible saving to be effected through even a slight improvement in the industrial quality of a laboring population. The total product will then be represented by the line ay.

Our question is: To whom will go that portion of the produce which is represented by the dotted line xy, under the normal operation of economic forces?

I answer: If our analysis of the source of business profits is correct, this will go to the laboring class in enhanced wages.

Let us see. To whom else should it go? To the landlord class in higher rents? No, clearly not, since the materials employed in production have not been increased, but the gain to production results from a better economy of materials, in kind and amount as before. Hence, no greater demand is made upon the productiveness of the soil; hence, cultivation is not driven down to inferior soils; hence, rents cannot be enhanced, rent representing only and always the excess of produce on the better soils above that of the soils of the lowest net productiveness under cultivation. The line ab, therefore, remains unchanged.

Shall the line bc show any change? Shall all or any part of the gain xy go to the capitalist class as interest? Again, no. An improvement in the industrial quality of the laboring class does not necessarily increase the amount of tools and supplies required in production. On the contrary, neat, intelligent, careful, workmen require even fewer tools than ignorant, slovenly, heedless workmen, to perform the same kind and amount of work, since in the case of the former there will be a smaller proportion at any time broken or dulled or from any cause awaiting repair. Since, then, there is no greater demand for capital in the case supposed there can be no increase in

the rate or amount of interest; and the line *bc* will therefore not be lengthened.

Will the whole or any part of *xy* go to the employing class, as increased profits? If we have correctly discovered the source of business profits, this will not be the case. An improvement in the industrial quality of a given body of workmen would not necessarily require any increase in the number of employers; hence, would not, could not, enhance the aggregate amount of profits. On the contrary, an improvement in the industrial quality of the laboring class would tend, and would tend strongly, to raise the standard of business ability in the employing class; to drive out the more incompetent, thereby raising the lower limit of production in this respect, and thereby reducing the aggregate amount realized as profits.

We see, therefore, that the line *cd* will not be increased in the case supposed; and, as we have proved the same respecting *ab* and *bc* successively, the whole of *xy* must go to lengthen the line *dx*, representing the amount previously received by the laboring class as wages.

We have thus far, for convenience of reasoning and simplicity of illustration, assumed that the economic effects of the improvement in the industrial quality of the body of laborers in view are confined to an increase in the amount of the finished product through a diminution in that element of waste which enters into all production of wealth. The same argument would hold good of an improvement in the industrial quality of the laboring population which should result in the production of goods of equal bulk and weight, but of a greater value through a higher quality, a more perfect finish, a nicer adaptation to the wants of the community. Not only is such an increase in the value of the product, which does not increase the amount of materials taken from the soil and hence has no tendency to enhance rents, possible, but instances of this character are, more than any other, representative of the modes of production in communities of a rapidly advancing civilization. In all such cases, the increase of value due to the improvement in the industrial quality of the laboring classes would, under the principles laid down in this paper, go entire to the laborers themselves, granted only perfect competition.

But such an improvement in industrial quality would probably be followed, sooner or later, by an actual increase in the amount of material employed. In this case, what would be the distribution of

the produce? The increase would no longer go entire to re-enforce wages. A larger amount of materials being used, a greater demand would be made thereby upon the productive powers of the soil; the lower limit of cultivation would be pushed downwards, a longer or shorter distance, to supply the increased demand; and rent would be enhanced, as in all prosperous and progressive countries it certainly tends to be. But can anyone believe that all the increase in the total product would go to increase rent, or even that rent would be increased more than in the proportion of the increase in the total product? If not, then, the portions reserved as interest and profits remaining unchanged, the share of the laboring class must be increased.

But suppose, again, that the improvement in the industrial quality of the laboring class is carried to such a degree as to qualify them to use a higher order of tools, more complicated, more delicate, and hence more expensive, than before. Here we should have an increased demand for capital; and, by consequence, supply remaining for the time the same, interest would be increased. But can anyone believe that the capitalist class would receive all, or even for any long period the greater part, or, in permanency, even any considerable part of the resulting gain to production? On the contrary, it seems to me too clear to require formal argument that the main advantage of such an improvement in the industrial quality of the laboring class will be at once appropriated by that class in higher wages; and that, in the course of time, the whole of that advantage must be so appropriated, the rate of interest tending, as we know, strongly and swiftly to decline.

In the foregoing illustration we see the importance of the economic attitude which, if our analysis has been correctly made, the laboring class occupy, as the residual claimants upon the product of industry. It is not for a moment to be supposed that the theory of business profits here presented accounts for all the facts of the case; that the principles adduced govern the remuneration of the employing class without extensive qualification. I only present this as affording a theoretical determination of this share of the product of industry, upon the assumption of perfect industrial competition. I have mentioned some of the causes which prevent profits from being kept down to the limits within which such competition would hold them. The discussion of these and other causes operating to the same end might profitably be extended.

I believe that the theory here offered accounts for the actual facts of business profits about as nearly as the Ricardian doctrine accounts for the actual facts of rent. This is all that is claimed for it. If so much be conceded, it must, I think, be seen that we have, for the first time since the wage-fund theory was exploded, a complete and consistent theoretical determination of the several principal shares into which the product of industry is divided.

The bearing of this view of the source of business profits upon the socialist assumption that profits are but unpaid wages is too manifest to require exposition. That this view of business profits, if fully understood and accepted by the wages class, would have a truly reconciling influence upon the always strained and often hostile relations between employer and employed cannot be doubted.

MEETING 361.

Railway Tracks.

BY MR. P. H. DUDLEY.

The 361st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 28th, at 8 P. M., Mr. Thomas Doane in the chair.

After the reading of the records of the previous meeting, the election of new members, and the transaction of some other business, the chairman introduced Mr. P. H. Dudley of New York, who read a paper on "Railway Tracks, and a Brief Description of the Dynagraph and Track Inspection Car."

Mr. DUDLEY said: It is a well-recognized fact that the better the track can be made the less the friction of the trains will be, or, in other words, the less the cost of transportation.

While we look upon the present locomotives as the most powerful motors extant, per cubic foot of dimensions, the emblem of our phenomenal progress, we must not overlook the fact that underneath

their drivers there must be a good track in order for them to reach their highest duty and usefulness.

The best tracks of today are the result of the study and experience of nearly half a century's work; nor have we reached the summit of perfection; but improvements are being constantly made. Thousands of active minds have been and are engaged upon important problems, the solution of which adds to the vast sum of practical knowledge.

Railway officials are now looking into matters for the purpose of saving small fractions of a per cent in some of their operations, many of which are of such magnitude that a small per cent of saving amounts to vast sums.

It is not strange, but rather to be expected, that there should be differences of opinion as to the best methods of construction, etc., owing to different local conditions.

Take the railways leading out of this city, and in the matter of joining the rails it is quite correct to say that each has a special plan.

In weight of rails, all are now laying those of 72 pounds per yard, yet each road has a different section, a slight modification in form and distribution of the metal, hoping thereby to reduce the cost of operation and maintenance. Briefly, these differences indicate, in some measure, the efforts on the part of officials to obviate some forms of wear, which experience shows takes place on their lines. It is but the constant repetition of practically testing ideas to keep pace with the needs of traffic and consequent wear, which has taken place ever since rails were used.

The first rails were of cast iron; these were replaced by the strap rails, which were from one-half to five-eighths of an inch thick, and two inches wide, spiked to a longitudinal stringer, and were considered, at that time, heavy rails. Previous to 1831, Colonel John Stevens invented our present form of rails.

All of the first rails used in this country were rolled abroad, and were very expensive. In most cases the quality of the material was excellent, but their cost led to the adoption of very light sections. The joints were and still continue to be a source of great trouble; they would go down, causing an unpleasant jar as the cars passed over them.

To obviate this, various joints were introduced and tried; also

several forms of compound rails, riveted together in long sections. These seemed good when new, but were of short duration; the expansion and contraction destroying them.

The inverted U rail was extensively used, but it did not serve for the increasing traffic and heavier locomotives which were required. More iron was then put into the section of the present form of rail, and those which were made of good material did efficient service for those times. As the weight of the rail increased, the quality of the material decreased, and many of the large rails did not give as much service as the smaller and better-worked sections had done.

The piles from which the rails were made were formed in part from old rails, with new iron for the head and base; the pieces of iron did not weld thoroughly as they passed through the rolls, and in service the ends crushed or a portion of the head flattened and broke. It was not possible to maintain the surface of the track long, as many of the rails did not last three months before requiring renewal.

The cost of transportation on the best constructed tracks was, as late as 1855, nearly two cents per ton mile, and on many tracks it cost more than the charters of the railways allowed to be charged. Three cents per ton mile was then considered a low rate, which today would close your manufactories. As the volume of business increased per year the cost per ton mile decreased but little, for each ton of freight meant a proportional amount of destruction to the track.

At the time of our civil war the railroads were taxed to their utmost, and better rails were demanded. Some of the crucible steel were tried and found good, but their great cost prevented more than experimental use. Booth's steel-capped rails were next tried, and proved of some value; but the caps of steel, not being welded to the iron of the rail, broke and split under the traffic much faster than was expected.

During these experiments in this country, Bessemer in England was at work on his process for making steel direct from pig-iron, which he finally brought to a successful conclusion. It gave a product the use of which has rendered possible the great extension of railway tracks, reducing the cost of transportation to one-quarter or one-fifth of former sums.

The light steel rails of from fifty-two to fifty-six pounds per yard gave such good results, by holding up and permitting a better

surface of the track than was possible with iron rails, that heavier locomotives and cars were built to accommodate the increasing traffic. When these were put into service they increased the deflections of the rail, which eventually acquired permanent set at the joints, increasing with the length of service.

Studying the forms of permanent set of the rails upon a number of roads a few years since, I found they could be mostly referred to three primary forms.

1st. Those low at the joints and high in the center as it appeared to the eye in the track. This is the most common form.

2nd. Those low at the joints and also at the center.

3rd. Those which had a considerable number of undulations throughout their entire length. This form was quite common in some brands after the change was made from the light to the heavy, or deep-headed rail.

They gave a tremor to the cars which caused the riding to be unpleasant to the passengers.

The trackmen were unable to overcome this feature, and no matter how well they maintained the joints, the track did not ride smoothly, nor could it be long kept in surface.

Each mill gives a slight difference to the finish of its rails, which is often sufficient to enable me to tell from the original diagrams, made by my apparatus, the brand of the rails over which I am passing if they have not been laid over two years. Some of the mills gave the subject immediate attention, and the rails have been much better of late, and can be further improved by better methods of straightening. Another form of rails which I have found in the tracks the past three seasons is the reverse of the first form mentioned above, high at the joints and low in the center.

With angle plates this rarely occurs, except in tracks nearly in their best condition; the rails appear to the eye nearly in surface, the centers only deflecting under the passing train.

When these deflections do not exceed a central depression of one-eighth of an inch in eleven feet, they are hardly noticeable in a passenger coach; but when they are more, or that amount in shorter distances, they are perceptible.

The development of the forms of permanent set in the track is one of great interest, and has quite definite relations to the section of

the rail, joints, the kind of wood used for cross-ties, ballast, tonnage or service, and the care or labor given to the track. The rapidity of development is not the same upon each road, but depends somewhat upon the system of placing the joints of the opposite rails. If both joints are placed opposite upon the same tie, or between the same ties in case the joints are suspended, the development of the first form is most rapid as a rule. If the joints are alternate, then the second form develops first, and usually changes to the first form, unless the track has special care. If the rails are already in the first form of permanent set and the traffic heavy, trains running in one direction, as they do on double-track roads, the receiving end of the rails becomes cut out on top. Five or six years ago it was very common to find the rails cut out in this manner on most roads

The discharging end of the rail is uninjured to any marked extent, though it becomes cut under the head by the reciprocal wear of the fish or angle plate. The shock of arresting the descending wheels is very great, and the friction of the moving trains increased, while the car trucks are severely shaken, nuts loosened, bolts broken, thus increasing both car and track repairs. The effect of such shocks on the rails of the elevated roads in New York city is very marked.

The frequency of the trains prevents any such care of the joints as can be given to those of the surface roads.

On the Third avenue alternate joints were used, and on many rails which were recently removed the receiving ends of the rails were much worn. The shock of the wheel at the joint has been conveyed through the axle to its mate on the other end, sufficient not only to indent but cut out a portion of the center of the rail opposite the joint. I have never found the center of the rails cut out as much on the surface roads, though the effect of the shocks can be traced. On tracks laid with opposite joints I find the cutting out of the ends of the rails more rapid than with alternate joints; and on several roads this has reached such an extent that they are taking up the rails, cutting off the injured ends with a high-speed friction disk, redrilling and relaying them, as the center portion will do further service.

The cutting out of the rail end is now much decreased, since the adoption of the higher standards of track. Joints which do not deflect, upon an average, over 3-16 of an inch as the central depth in about ten feet, cut out so slowly that little increase is noticeable each year.

The benefits to a road in raising the standard of track are, besides the saving of the rails, a reduction of the friction of trains, consumption of fuel, car repairs, and other operating expenses. The difference to a trunk line in the cost of transportation over a track where the average deflection per joint was 5-16 of an inch, and over another track where the average deflection was only 3-16 of an inch, represents such vast sums that those who have not investigated it can hardly credit the amounts. The data for such calculations I have obtained from my diagrams of different roads, and the figures agree as closely as could be expected. A reduction of ⅛ of an inch from the 5-16 of an inch deflection shows a saving of from 1.4 to 1.5 mills per ton mile. The first 1-16 of an inch saved about 0.8 of a mill, and the next 1-16 of an inch saved about 0.6 of a mill per ton mile.

One of the trunk lines' tonnage for 1875 was 2,100,000,000 ton miles, and this business was done at a cost of over 1.5 mills per ton mile more than what it cost two other trunk lines to do their business on much better tracks the same year. The extra cost of 1.5 mills per ton mile on their business represents $3,150,000. This means that a large portion of that sum could be expended over and above the usual yearly allowance for improvements in the track, and if properly applied, would be saved in the current expenses of operating. In making such a statement public I am not only relating what ought to be, but what has already been, accomplished by some roads, and others have good precedents to follow.

These actual facts only confirm what our ablest railway officials have long maintained,— that one of the first requisites in the reduction of expenses is a good track. With that other desirable improvements follow.

The average cost of transportation per ton mile on the best tracks today is about 4 mills; the average rate received is from 5½ to 6 mills. So far as I can obtain figures no country shows such a low rate of cost of transportation, or are the charges as low as they have been here on the trunk lines.

To give a tangible idea of the cost and system of transportation, the charge on a barrel of flour from Chicago to Boston has been less than its cartage would be for three miles in your city. Such practical facts are in one sense the measure of the remarkable progress and improvement in railway tracks and appurtenances the past few years.

The curvature and topographical features of a railroad, stopping trains at stations, all affect the wear of the rails so that a uniform condition of track per mile is not likely to prevail for any length of time, the section of rail and brand, ballast, and ties, also modify the condition per mile. At the stations on the curves and gradients the wear is more rapid and uneven than on other portions of the line.

On tangents the loss of metal due to wear is confined to the top of the head and base of the rails; the width of the head is not reduced, but frequently made wider on account of the flow of the metal. In some cases oxidation takes place, reducing the web and upper side of the base of the rail.

This occurs at street crossings, the rails being planked on both sides, at water stations, and in tunnels. The wear which takes place on the base of the rail is caused by the rail not being kept tightly spiked. In soft woods, as chestnut, hemlock, white cedar, and yellow pine, this is a very difficult matter and requires constant attention. The spike draws, the fibers of the wood are indented, and after they are once started, the deflections of the rails, together with the dust, abrades them with great rapidity, this is more rapid on curves and gradients, and on the first the rails roll so as to spread or increase the gauge.

On curves, the wear is the greatest on the inside of the head of the outer rail. This is caused by the flanges of the wheels grinding against the rail, and the greater the angle at which the flange of the wheel strikes the side of the rail the more rapid the cutting. The cast-iron wheel flange does not cut so rapidly as the steel. The wear of the rails on curves is more rapid on any road than on the tangents, and is increasing with the heavier tonnage and steel-tired wheels.

The reciprocal wear of the tires of the wheels is also great, and how to reduce it is a problem. This wear is more rapid on narrow-gauge tracks, from the fact that the rail heads are only about two-thirds as wide as those of the standard gauge. The same brand of tires on the locomotives only run about fifty thousand miles over them before requiring turning; while on the standard gauge they run from seventy-five to eighty thousand miles. In the case of the rigid truck on the locomotive, the side wear on the head of the rail on curves is less than for the swinging truck, but the wear on the tires is greater in the first case. The wear of steel rails or tires is not by

a uniform loss of metal over the surface, but it comes out in small particles, leaving an irregular surface. The better physically the quality of the steel the smaller are the particles, and the smoother the surface, and the longer the steel wears.

Under the wheels of the cars and drivers of the locomotives, the pressure per square inch of the surfaces in contact in most cases exceeds the elastic limit of the steel, measured by the usual method of tension. The limit rises on the surface of the rails and tires, but is still insufficient to prevent rapid flow and loss of the small irregular surfaces in contact.

The slow rate of wear of the light-headed rails under the then existing wheel tonnage was studied, and deeper heads given to subsequent rails, for supposed increased service. Experience now shows that rails do not wear down in a smooth, uniform manner, but, on the contrary, the wear is very uneven per length of rail, and they are removed from the track on that account before they are fully worn out.

What is needed today for present, and to anticipate the average, increase of wheel tonnage is to widen the head of the rail, thus increasing the surface of contact, in order to distribute the weight over larger areas, and thereby check the rapid loss of metal.

To check the deflections, stiffer sections of rails are needed, or in other words, the material must be distributed so as not only to decrease the rate of wear, but make a stronger rail. The problem is not wholly one of weight of rails, but also of form.

The heaviest rail in use now is eighty pounds to the yard. The section as used by the New York Central & Hudson River Railroad is five inches high and nearly the same width of base, the head is $2\frac{3}{4}$ inches wide but comparatively shallow. The upper corners of the head are 5-16 of an inch radius, while that of the top is 12 inches, giving a broad bearing surface for the wheels, thereby checking the rapid increase of wear. The increased wear of the treads of all the wheels is of far more importance than the small percentage of wheels condemned for sharp flanges.

The 72-pound rail which has been in use on the Boston & Albany Railroad since 1880 has been brought to such good surface in the track that only from five to eight deflections in length of 11 feet under the weight of a 34-ton car exceeded one-eighth of an inch per mile.

[illegible] of his "Dynagraph and [illegible] car an accurate record of [illegible] car passes over it is made [illegible] under the head of the rail at [illegible] is more than a certain [illegible] the section men the exact [illegible] time a car is run over a [illegible] the deflection is more than [illegible] trips this is reduced some-[illegible] and in one case to three thirty-[illegible] as close as it is possible for the sec-[illegible]

[illegible] the car, taken from several roads, [illegible]

A [illegible] were projected on the screen [illegible] of the subject.

[illegible] thanks to the speaker for his [illegible]

MEETING 362.

[illegible] Fire Alarm.

[illegible]

[illegible] SOCIETY OF ARTS was held [illegible] Mr. C. J. H. [illegible]

[illegible] meeting, and [illegible] Committee presented [illegible] year.

[illegible] and ordered [illegible]

The Permanent Meteorological Committee then reported through its chairman, Prof. W. H. Niles.

REPORT OF THE METEOROLOGICAL COMMITTEE.

Prof. NILES said that the duties of the committee during the year had been unusually few. The Signal Station in Boston had been inspected by the members, both collectively and individually. It was found to be well kept, the instruments appeared to be in good condition, but the sergeants had not at all times been aided by competent assistants.

By the failure of Congress to make the requisite appropriations, the Signal Service had been forced to suspend some of the most important functions of the Weather Bureau. The Service had not been able to transmit by telegraph the reports of the weather at various important points, hence the issuing, at Boston, of a daily weather map had been rendered impossible for a time. Such interruptions seriously reduce the value of the Signal Service to the country. It is much to be desired that the Weather Bureau should receive that financial support which shall enable it to prosecute its work effectively and continuously.

The published "Indications" of the weather had received during the year more adverse criticism than usual. In many instances the criticisms did not accord with the facts, but there have been good reasons for the belief that, in a broad country like our own, weather warnings can be made more accurate, and therefore more valuable, than ours have been during the past year. If there is not an improvement in the "Indications," it may be well for the members of the Society to express their united request that a weather service should be so sustained by stated and adequate appropriations that the best efforts of the most competent men may be continuously employed in work which shall yield the greatest benefit to commerce, agriculture, and other industries.

THE MARTIN-WILSON AUTOMATIC FIRE ALARM.

The chairman then introduced Mr. A. H. Kendall, who read a paper descriptive of the "Principles of the Martin-Wilson Automatic Fire Alarm."

Mr. KENDALL said: The sharp competition of today is forcing business into conditions where it can obtain only reduced profits, which formerly would not have been considered to be an equitable remuneration for the capital invested. And these sparse profits in commercial affairs and manufacturing enterprises are now made out of what was wasted a few years ago. One of these items is the fire waste as represented in the cost of insurance, which is of course strictly based on the actual destruction of fires. The general consideration of insurance a few years ago was treated as an act of fate. There was but little elasticity in the matter of insurance rates, and if any economy was exercised, it was in the reduction of the amount of insurance rather than seeking to diminish the rate, and still preserve an amount of insurance adequate to indemnify the assured to an equitable degree in case of fire. The systematic effort to reduce the rate of insurance by improved construction and fire protection is one of the most modern features of business. The aggregation of values in our business centers, with large buildings closely crowded together, and the augmented fire hazards from these conditions, as well as from the greater speed of machinery, and the introduction of many processes in industrial chemistry, such as drying at high temperatures, and the wide use of artificial light, have increased the risk of fire to an extent far beyond the conditions of less than a generation ago.

At the same time, the defences against fire have been increased. Our fire departments have been developed until, both in organization and equipment, they resemble a standing army. The power of the law is exercised in the same direction, limiting the quality of illuminating oil, its methods of storage and sale, and in cities the construction of buildings to the utmost detail practicable with enforcement. But, nevertheless, the terrible ravages of fire show that these precautions have not kept pace with the increasing conditions of hazard, and I appear before you this evening to offer a few words in explanation of the latest application of modern science to this problem as represented by the Martin-Wilson automatic fire alarm, its function being that of an ever-vigilant custodian by its instantaneous operation to sound an alarm which will save the precious seconds at the beginning of every fire, and summon the assistance of the fire department and other help at the earliest moment. Captain John S. Damrell, for many years the chief of the Boston fire department, and now at

the head of the bureau of building inspection, once uttered a great truth in saying that a great fire was a neglected small one.

I purpose submitting some facts relative to thermostats in general, and their application to the Martin-Wilson automatic fire alarm system in particular, with a comparison of the different systems of application. It is useless at this late day, when the losses by fire in the United States are so heavy that fire insurance has almost ceased to be a profitable business, to go into the question of the value of an automatic fire alarm. Any invention or application that is absolutely certain to automatically indicate the location of a fire in a building in its incipiency before it has had time to do much damage, and when it can be easily extinguished, deserves the earnest attention of insurance companies, property owners, capitalists, and the general public.

The foundation of an automatic fire alarm is the heat detector, and this company claim that their heat detectors or thermostats are at once the most scientific, the simplest, and the most reliable instruments yet invented; and that their system of electrical circuits and apparatus used in connection therewith, for the purpose of sounding a fire alarm by the heat of the fire itself, cannot be excelled. The idea of utilizing electricity to give notice of undue heat is by no means a new one. But the great difficulty has hitherto been in its execution, from the fact that a fire being of comparatively infrequent occurrence, the circuits, by reason of an accidental break, earth connection, or a weak battery, would be apt to be in an inoperative condition when a fire occurred, and so fail to do the work expected of them. In 1830, Dr. Ure, the celebrated English chemist, invented a thermometer in which the movement of a spring composed of two unequally expansible substances, for instance brass and steel, indicated the temperature to which it was exposed. This instrument he called a thermostat, and he utilized its motion to regulate the valves or dampers of furnaces, and since that time thermostats and thermometers embodying the same principle have been devised by different inventors, a familiar example being the common metallic thermometer. From 1830 to 1881 numerous thermostatic heat detectors were invented, based on various principles, such as the expansion of metals and air, beeswax, and similar substances, and the rending or rupturing of fragile vessels by the vaporization of volatile liquids, such as alcohol, ether, etc.

Nothing so practical or so reliable as the metallic expansion thermostat of Dr. Ure was, however, produced until 1881, when Mr. M. Martin of Boston invented a thermostat in which the low boiling or vaporization points of such fluids as ammonia, alcohol, ether, naptha, etc., was successfully utilized to control an electric current and give an alarm when a determinate temperature was reached. In the Martin thermostat a very small quantity of a suitable fluid is hermetically sealed within a thin metallic disk-shaped capsule or tank, having one of its faces made of a very flexible sheet copper and slightly concave, while the other face is comparatively rigid and unyielding under pressure. The application of heat volatilizes the contained liquid, and the expansive power of the vapor thus generated bulges the flexible face outward into a convex form with great force. And this movement is used to open or close an electric circuit, as may be desired.

Perhaps it would be as well to assume at this point that there may be some in the audience who are not fully informed in regard to the difference between what is technically known as a closed circuit and an open circuit, the latter being where the two wires both start from the battery, one from the negative pole, the other from the positive, and are separated at any point. As long as this separation exists there is no current, consequently no decomposition in the plates in the battery, the continuous current being produced by that decomposition which sets in through the acid in which the plates are immersed the instant the two ends of the wire are joined together and the circuit closed. In an open circuit the alarm is caused by the starting up of the current, which is supposed to be constantly in readiness to act, but, as will be explained to you later on, there are a number of possible and probable conditions which, given their existence, no current can start; and it can never be known if these conditions do exist until you attempt to start the current. Another form of circuit may be made with a wire and what is called a ground. Close up the gap, and the current immediately sets up through the earth, which completes the circuit.

A closed circuit, on the other hand, as its name implies, gives a continuous current which is either metallic or ground, and the alarm is given by any interference or weakening of the current. Consequently it is always testing itself, and any complication that in any

way interferes with its perfect working at once sounds its own alarm. So you will at once perceive that, other things being equal, the closed circuit is, without question, far superior to the open, inasmuch as in one we hope for the warning, in thè other a failure to receive it is an electrical impossibility. What has heretofore prevented the general use of the closed circuit has been, first, the much greater expense, and, second, the supposed impossibility of making the different alarms intelligible and distinct in themselves.

After a long series of experiments with thermostats variously constructed, embodying the foregoing principles of operation, the Martin-Wilson Automatic Fire Alarm Company have finally adopted two, one an open and the other a closed circuit instrument, which are simple and effective as practical heat detectors. In both forms, the tank or reservoir is held firmly suspended in a dish-shaped frame, with its rigid face downward and its flexible face upward. The latter, coöperating with the circuit controlling parts, which are attached to the rim of the frame, is slotted to freely admit the surrounding air to the surface of the tank, and also to protect it from accidental blows, while, to exclude dust or dirt from the working parts, a cap or cover is closely fitted over the rim of the frame, great sensitiveness and little liability to injury or derangement being thus secured. It will readily be seen from this description that, while the contact points operated by the movement of the upper surface of the tank are protected from dirt or dust by the cap or cover, the under surface is directly exposed to the air, which easily passes through the slots in the supporting and protecting frame, and that any change in the temperature is very quickly communicated to the contained liquid. Hence the instrument is extremely sensitive, and at the same time is perfectly protected from injury or derangement of any kind, a combination of results hitherto unattainable.

Delicate and consequently uncertain adjustments of contact points to vary the operative temperature, a feature so objectionable in most thermostats, are eliminated from this instrument, as each reservoir operates at a certain definite temperature dependent on the character of the liquid contained therein, and as the reservoirs can be readily taken out of or inserted in the supporting frame, the temperature at which it is desired any instrument shall operate is readily controlled.

The two kinds of thermostats most used at the present time are

known as the mercurial and the metallic. The former is really a miniature mercurial thermometer in which the rise of the column of mercury closes an electrical circuit at a certain point. It is a very fragile instrument, and besides its contacts are not to be depended upon. The latter is Dr. Ure's thermostat reduced in size. Its faults are: —

The dust screen, which acts as a heat screen as well, and greatly reduces the sensitiveness of the instrument.

The feebleness with which the circuit is closed.

The absence of frictional or rubbing contacts.

The danger of injury to the compound spring by its continual movements in response to every variation of temperature.

Great liability to give false alarms by jars or vibrations.

In contradistinction, a few of the points of superiority possessed by the Martin hydro-carbon thermostat are as follows: —

The sensitive and operative part is exposed directly to the air, and the contact points are perfectly protected from dust or dirt.

The absence of delicate screw adjustments to vary the operative temperature.

The great energy with which they open or close the circuit.

All contacts are rubbing or frictional.

Quiescence of the sensitive and operative part until the specific temperature at which the alarm is given is reached. Entire freedom from false alarms by vibrations or jars.

The instruments are made in the most substantial manner, are nickel-plated, and present a very ornamental appearance when placed on the ceiling of an apartment. Each has its operative degree plainly printed thereon, and we furnish reservoirs operative at any degree from 90 to 200 Fahrenheit. A reservoir may be used a great many times without injury, provided the heat applied is not too great. The neatest and most convenient way of connecting this thermostat in position is by means of porcelain knobs screwed into the ceiling about four inches on either side thereof, the knob serving to support both the instruments and the connecting wires.

Our system differs from every other in our method of using a closed circuit, wherein the wires are constantly charged with electricity and always ready for service. Its service is not limited to giving an alarm of fire, which is specific, indicating both by sight and sound

the cause and location of the difficulty, but it also signals without giving a fire alarm anything tending to any interference whatever with the full operation of the system, such as any break, derangement of the system or weakening of the batteries before they become inoperative, whether it be caused by neglect, accident, or design; in short, a fire produces a fire alarm, and any fault in the system makes an inspector's alarm. Each class of signals is of separate and distinct nature, and never to be confused, as they are both visual and audible. We submit that no electrical apparatus contains such a wide range of operation, all of them of the highest practical value, and possessed by no other automatic alarm. And these results are not accomplished by any complex mechanism, but each function of the system is operated by devices simple in themselves, and all tributary to the desired result of obtaining a guaranteed safety under all circumstances. An automatic fire alarm with open circuit is dead until a fire is presumed to scorch it into life. Its complete arrangement can never be assured in any other manner. A broken wire, faulty connection, or weakened battery, or some obstruction, may exist without knowledge on the part of anybody, and if so, when the circuit is called on for action, it will fail to respond, thereby rendering the whole plant completely inoperative. It only remains to say that a closed circuit is acknowledged by all to be the best in all cases where it is essential to give a warning when a conducting wire is broken. But up to the present time the extended use of such a circuit has been deemed impracticable in automatic fire alarms, on account of the accidental breaking of the circuit giving an alarm identical with that given by the heat detector or thermostat, the only other objection heretofore having been the increased cost of maintaining the batteries, owing to the forcible and constant current passing through them. This has been the riddle that electricians have been trying to solve for years, and the best evidence of its solution by arrangements peculiar to this system for economizing the amount of battery power constantly used is that we are able to compete with any system on a basis of dollars and cents. Of its superiority there can be no question.

At the close of Mr. Kendall's paper the chairman introduced Mr. M. Martin, who gave a successful exhibition of the working of the apparatus, showing clearly that a broken wire, a ground, weak

batteries, etc., signal for an inspector without sounding the fire alarm; that it gave notice when these difficulties were repaired; that even before they were repaired a fire in that circuit would ring an alarm. Mr. Martin also answered several questions concerning the detail working of the apparatus.

MEETING 363.

Submarine Signals.

BY MR. JOHN M. BATCHELDER.

Electrical Distribution by the Aid of Induction Coils.

BY MR. M. M. SLATTERY.

The 363rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, May 26th, at 8 P. M., Prof. Charles R. Cross in the chair.

After the reading of the minutes of the previous meeting, the Secretary read a paper by Mr. John M. Batchelder, on "Submarine Signals."

Mr. BATCHELDER said: This apparatus is intended for giving signals, or for affording communication between steamboats, steamships, or other vessels during a fog or by night. The system is entirely acoustic, and has no relation to visual or to electric signals.

Upon the steamer or vessel a pipe is connected with the steam boiler, its upper orifice being within the steam space or chamber above the water and its lower end immersed in the open water alongside of the vessel, which is supposed in this case to be the sender of the signal or message.

The steam pipe passes through a scupper or port-hole, and has at any suitable point in its length a common stop-cock or valve, provided with a handle or lever that can be turned, to open or close the cock, and admit to or exclude from the open water a jet of steam, at

any required intervals of time. As the jet of steam enters the cold water that occupies the space between the two points of observation it is condensed,—a vacuum is formed, and a loud cracking or snapping sound is produced.

The description thus far relates to the sending apparatus;—the receiving part consists of a drum, or tympanum, provided with a socket in which a wooden rod, or a metal tube, a wire or other good conductor of sound is inserted. This rod or tube leads from the tympanum to the ear of an observer on the vessel or steamer that is to receive the signal or message from the other steamer. The drum is made of sheet metal, that is sonorous, and may be about one foot in diameter and an inch in thickness. Air is enclosed in the drum, which is submerged by an attached weight to the depth of a few feet below the surface of the water. It is not necessary that the drum should be on the same level as the lower end of the steam pipe, as the sound and vibration proceeds in all directions.

In the case of two steamboats nearing each other in a fog, both being provided with the apparatus for sending and receiving signals, the sounds may be often repeated, to call attention. If the course of a distant boat is wanted, a message may be sent by the use of the telegraphic alphabet.

The velocity of sound in water is about four thousand seven hundred and eight feet per second, equal to about nine-tenths of a mile, therefore, for all practical purposes in its use for signals, its transmission for several miles may be considered as instantaneous.

When vessels are near each other the loud cracking sound of the steam, as it escapes in the water, may be heard by using a small tube of metal, open at both ends, or a wooden rod, as receivers of sound; in this case the tube or rod should enter the water about two fathoms in order to present sufficient surface to the action of the sound waves, the other end of the tube or rod being held to the ear of the observer.

This system of signals is suitable for giving to passing vessels notice of the proximity of dangerous capes, headlands, or shores, special provision being made at these points for generating steam to be applied as herein stated; it can also be used between terminal stations, or positions that are not in the line of direct vision.

The stop-cock in the pipe may be placed near the steam generator, and a rubber hose used for the conveyance of steam to the open

water; when used in this manner the outer end of the hose should have a metallic nozzle two or three feet in length to increase the resonance.

Trials of this system have been made during the past two or three years with very favorable results. In one case a common rubber hose forty feet in length, and three-quarters of an inch in diameter, was attached to the try-cock of the steam boiler used at the draw of Charles River bridge, and led over the wharf into the water. The steam pressure was thirty pounds to the inch, and at the orifice of the hose was the half of the common brass coupling. The tympanum or receiver of the sound waves was at the Milldam, one mile distant from the boiler. The steam was let on, and shut off, by turning the try-cock in accordance with the Morse alphabet, and the signals were distinctly heard at the point above mentioned.

The distance that can be covered by this system of marine signals is not yet fully determined; it will depend upon the temperature of the steam, the kind of tube used for its discharge, and the sonorous qualities of the metallic drum, or receiver.

ELECTRICAL DISTRIBUTION BY THE AID OF INDUCTION COILS.

The chairman then introduced Mr. M. M. Slattery, Electrician of the Sun Electric Co., of Woburn, who read a paper on "Electrical Distribution by the aid of Induction Coils."

Mr. SLATTERY said: It is now generally admitted that, in the histories relating to the various branches of industry in this country, there is no branch which in so short a time has shown so much intellectual activity, energy, and enterprise as electric arc and incandescent lighting; and in reviewing the efforts of the past five years one is caused to wonder not so much at the innumerable improvements which have developed from time to time as at the completeness and boldness with which these improvements have been placed at the disposal of the public.

From the time of the first great efforts in 1878, of Charles F. Brush, the pioneer of the commercial arc-light system, to the latest outcome in the same direction,—from the days of Edison's first attempts to make incandescent lighting a commercial success, down to its present stage of perfection and utility, improvement after improve-

ment has followed in such rapid succession that our sense of satisfaction at having placed within our reach one of the most valuable acquisitions to modern civilization is only equaled by that produced by its rapid growth and its many opportunities for application.

We all no doubt recognize that the year 1878 will ever be memorable in the history of electric lighting, for the reason that the first real practical developments took place in that year; and, although the efforts of that time may seem to sink into insignificance by the side of the perfected work that we may now see around us on every hand, yet in that year the proper direction in which to work was truly outlined and indicated, and a line of action pointed out which was subsequently followed up by the two gentlemen referred to with a persistence and ingenuity that must ever elicit our admiration and respect.

However, as time rolled on, and the magnitude of the work began to assume considerable proportions, it was found that the arc system of lighting outstripped the low tension incandescent system, principally because the problems involved in the respective systems were very much simpler in the one case than in the other. In the latter case the necessity of having to deal with very heavy currents, and the equal distribution of these currents throughout the system, required all the ability that the practical electrical engineer could bring to bear upon the work to be done to do it in such a manner as to keep that work within the limits of a profitable commercial undertaking; and how ably and well that work has been done is evidenced by the successful and gigantic undertakings that are being continually carried out.

Notwithstanding these successful undertakings on the part of the low tension incandescent advocates the time has now arrived when, in consequence of the enormously increased magnitude of the demands of the public for a more general extension of incandescent lighting, we find a necessity imposed upon us, in order to meet those demands, of making some radical departure from the lines in which we have hitherto been working, or, on the other hand, neglect the public's requirements, and confine our operations within certain narrow limits.

The object of my remarks this evening will be to endeavor to show the advantages of the use of a system of electrical distribution by means of induction coils, and how nearly such a system fulfills the necessary practical, economical, and commercial conditions imposed upon it.

As has often been remarked, in low tension incandescent lighting as hitherto carried out, there are two fundamental objections which present themselves to the practical electrical engineer. These are (1) the enormous mass of the copper conductors necessary to carry the current to the desired distance without a very prejudicial loss, and (2) the necessarily short distance from the source of generation of current to which that current can consequently be conveyed. Now, in a system of incandescent electrical distribution by the aid of induction coils, these objections may be so greatly modified as that we may consider them as almost wholly removed. It is well known that the higher the electrical pressure at which we work the smaller need be our conductors, and the longer may be the distance between the source of generation and the points of electrical distribution. Coupled with these two important elements must also be the one of such flexible sub-division and distribution as are offered by the beautiful low tension parallel arc systems now in operation. The efforts of many explorers have been directed towards securing each of these essential features. In 1883 one of the most successful of these suggested the proper disposition of induction coils in a system of this kind, viz., in multiple arc. If this gentleman had gone a little farther and given us some definite ideas as to the best proportions and construction of the coil, his suggestions would have been of more practical value, but as he left that important part of the subject still in the background, to be worked out by patient experiment, the brilliancy of the idea possessed a somewhat nebulous luster. The suggestion of the true line in which to work was undoubtedly an important step in the right direction, and experimenters set themselves to work to overcome the various mechanical difficulties which still presented themselves as serious obstacles in the way of success. These were from time to time removed, until at the present moment the system of electrical distribution by the aid of induction coils stands as embodying all the advantageous characteristics of the low tension systems, and as having eliminated the objections to short distance transmission with massive copper conductors.

We find that the first difficulties which the worker had to overcome were how to proportion his copper and iron in his coil so as to secure the best results, and so to combine such proportions as to obtain such an automatic regulation in the coil that the potential at the ter-

minals of the lamps should be maintained constant, or nearly so, no matter how much the load upon the coil might vary. It was an easy matter to calculate the loss in the copper, knowing the resistance and the current to be carried, but it was not so easy to determine the number of convolutions, and the quantity of iron necessary. It was found by experiment that many of the rules which guide the best manufacturers in the construction of dynamo machines could be applied in the construction of these induction coils,— that is, the loss in the copper wire must be as little as possible, for obvious reasons, and that, as in the case of the field of the dynamo, you must keep well below the saturation of the core, and the magnetic circuit must be as short as possible. Should you depart from these rules a lack of regulation or efficiency will follow.

I may say just here that the courteous manager of the Boston Electric-Light Company has been good enough to give us current this evening from the Company's city circuit; and for the first time in this branch of lighting we are able to give a practical experiment from a practically operating commercial plant.

[The speaker here exhibited a coil in which the core was over-saturated when working at full load. On this coil there were 25 16-candle power lamps, each being 50 volts, and taking one ampere each. The units of the coil and of the circuit in which it is working are — at the poles of the dynamo 1080 volts, at the poles of the primary of this coil 1050 volts, the current in the primary with the 25 lamps on is 1.25 amperes. There are 50 volts at the poles of the secondary, and 25 amperes in the circuit. The resistance of the primary circuit is 16 ohms, the resistance of the secondary .059 ohm. We find therefore that there is a loss of three per cent in the main line, and five per cent in the induction coil. This is equal to a loss in the system of eight per cent, — not an excessive one by any means. It was noticed by the effect on the lamps that the regulation of this coil was poor.]

The law of self-inductive resistance (or, as it is sometimes called, counter electro-motive force) is a most beautiful and accommodating one; for instance, in this coil in the primary circuit we have an electrical resistance of some 16 ohms, and as the pressure at the terminals of that circuit is 1050 volts we should be taking not 1.25 amperes, but some 65 amperes, if it were not for this something which

enables us to take only just what current we require. Now, as we are in fact only taking 1.25 amperes, at a pressure of something over a thousand volts, we must necessarily have somehow or other a resistance, electrical or self-inductive, of a little over 800 ohms, and, in point of fact, that is what we have, and it is made up of the resistance of the wire, 16 ohms, plus the resistance of the self-induction, or counter pressure.

To illustrate how admirably this law works when variations in the circuit take place by cutting lamps out, we have placed one of these 50-volt-1-ampere lamps in series in the primary circuit. It will now be noticed that as lamps are switched out of the secondary circuit the lamp in the primary will grow dim, showing that, as the resistance in the secondary circuit increases by reducing the number of lamps less current is flowing in the primary. A few words will explain the action. Take a core of iron and wind thereon a primary and a secondary coil of an equal number of ampere turns, connect the ends of one coil with a source of alternating current and close the other through an object of comparatively low resistance. The energy in both coils will then be almost equal. In this case the resistance of the primary will be merely that due to the conductor itself, scarcely any self-inductive resistance being present, there being an absence of any free magnetism or polar development. The current impulses it will be understood are circulating in the respective coils simultaneously and in opposite directions, so that the magnetic field that would be developed by one impulse is, at the same instant, counterbalanced by an opposite impulse, and the self-induction of the primary is thus suppressed or neutralized.

[The speaker here exhibited as an illustration of that law an iron core having two coils of an equal number of ampere turns, the primary being placed in series with the incandescent lamps in the secondary circuit of the coil under exhibition.]

Now, as long as the secondary circuit of this subsidiary coil is closed, the lamps with which it is in series will burn at almost their ordinary incandescence, but the moment the secondary of the subsidiary coil is opened the lamps grow dim. The reason is obvious; so long as the energy in both coils is equal there exists no self-inductive resistance. When, however, the energy is greater in the primary than in the secondary resistance due to self-induction follows.

This development of counter electro-motive force, or self-inductive resistance, is just the condition of things that should and does prevail in these coils that we have here tonight, so that, if we now call this a 20-lamp coil, when we turn out all the lamps but one, there should be a resistance of some 21,000 ohms, plus the small electrical resistance of the wire. The evidence of that is this: one lamp in the secondary circuit of this coil takes only one ampere, therefore, there being nothing else in the secondary circuit of the coil, there should (and by the construction of the coil there can) be only 1-20 of an ampere in the primary circuit. Now we have shown that on the proper full load (20 lamps) only one ampere is required in the primary current, and consequently with double the resistance (10 lamps) in the secondary only one-half an ampere would be required (at constant pressure, be it remembered) in the primary, and, therefore (the neutralizing current in the secondary being reduced by one-half), there would be double the self-inductive resistance in the primary, 2000 ohms, and so on until with the same pressure there will be 1-20 of the current, and thus we have twenty times the resistance in the primary; therefore, we get 21,000 ohms of effective resistance in the primary circuit, or 1050 volts $\div$ 21,000 ohms $=$ 1-20 ampere.

We were speaking a short time ago of this particular 20-lamp coil not being good in the sense of regulation with the extra load put upon it, because we too nearly approached the magnetic saturation point of the core. Magnetic circuits are like electrical circuits in some respects; if you overload a wire, you will have a certain loss, and in the magnetic circuit the same general principle holds good.

[Mr. Slattery next showed a 12-light coil, which was constructed with due regard to the loss in the wire and other wasteful effects, and the regulation was found to be very close.]

At this point I should like to express my opinion that in actual practice there is no such thing as absolutely theoretically perfect regulation. It is well enough to talk about, but commercially speaking it is impracticable. However, the very slight variation which you may or may not have been able to notice in this 12-light coil, as between full load and one or two lamps, is, from a commercial point of view, quite good enough.

True, almost perfect regulation is only a question of putting

metal enough into the apparatus, but not to such an extent as would commercially preclude its use.

Again, in any extensive system of distribution it is an easy matter, so far as maintaining an even pressure at the lamp terminals throughout the circuit is concerned, to establish centers of distribution and to provide feeders and compensating devices for these centers. In the case of such a system, the wiring problems to be worked out would be very much the same as in the case of ordinary low tension supply, the requisite being to keep the working pressure throughout the system constant. In the plant, however, from which we are now being supplied, there are no feeders or centers of distribution at present, nor in all probability will there be for some time to come, as the object has been hitherto to avoid this complication by keeping the loss in the main line very low, so that connection may be made with the mains at any point throughout their length.

I was at a town in Connecticut a few weeks ago. There is a large induction coil plant in operation there. They make a large center in the principal lighting portion of the town. The system works fairly well, but rather heavy fluctuations in the light of the lamps occur at certain times and places in the course of the evening. This would indicate not a very close regulation of the coils, but with feeders and compensating arrangements that evil may be entirely done away with.

I notice that there is a rapidly growing desire for some means of measuring the energy supplied by the users of this alternating current. I am pleased to have to say tonight that means are at hand for meeting that requirement; and in a short time a device will be in use that in effect shall rival the delicacy of electrolytic action itself, at the same time far exceeding it in accuracy.

Much has recently been said concerning the difficulty of running alternating dynamos in multiple arc. While some have said they have done it, no one has given us any precise particulars as to what latitude we may allow ourselves with regard to varying speed and electromotive force in doing it. I have lately had occasion to try some experiments in this line. I had in operation upon separate engines two 400 16-candle-power dynamos, one running 400 lamps, the other 25. All the lamps were upon induction coils. One dynamo, working at full load, was making 1200 revolutions per minute, the other 1250. This

last machine had a difference of potential at its poles of 1060 volts, the other 1000 volts. By means of a switch, the two armatures were suddenly thrown in multiple arc. For a moment there was a slight sag of the belt of the lightly loaded armature, there being a momentary tendency on the part of the heavily loaded armature to drive the other in the opposite direction as a motor. Instantly, however, both machines fell into step, evenly dividing the load between them, both delivering at exactly the same pressure. This experiment shows us that we may allow ourselves considerable latitude in regard to speed and electro-motive force in coupling alternating dynamos in multiple arc. When switching an armature out of circuit, when two or more are running in multiple arc, it was found desirable to have a small bank of lamps in circuit with the armature you wish to cut out, in order to prevent any hurtful effects, because, at the moment of cutting out, the armature circuit would be open, and the field being fully excited there would be an infinite resistance in the circuit, the volts would, therefore, have a tendency to rise to a dangerous degree, but a bank of lamps across the poles of the machine will prevent that occurring.

A good deal has been heard within the last few months of self-exciting alternating machines, as if there were something very original and advantageous about them. As to the originality, it is decidedly problematical, and, in my opinion, the advantages, such as they are, are on the side of the separately-excited machine. There is no great difficulty in making a self-exciting alternating machine; on the other hand, without going into the whole merits of the question, which time forbids me to do on the present occasion, I will simply say that the construction of self-exciting alternate dynamos is quite familiar to any of the best continuous current dynamo manufacturers. The objections to them, or to any shunt-wound high-tension dynamo of 1000 volts or upwards, are, first, it is an expensive machine to build, and, in the event of the dynamo fusible plug for the main line giving way, when at full load, in consequence of a dead cross on the line, it will be a rare circumstance if the machine is not destroyed, because at the moment of rupture of the main the volts at the dynamo will rise enormously, and the current will discharge itself through some vulnerable point in the machine.

I find that it is necessary for me to apologize for not having en-

tered more minutely into distribution by the aid of converters. I feel and know that I have left many important points untouched; however, one of the principal objects of this paper will have been attained if I shall have succeeded in directing some increased thought towards this growing branch of electrical lighting, a branch that I believe in time will take precedence of all others, as it brings electricity in its most flexible and utilizable form, and by comparatively cheap means, within the reach of all.

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CONTENTS.

NOTICE.

The Society of Arts, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce.

Regular meetings are held semi-monthly from October to May, inclusive, in the Institute building: and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending October 1, 1888, most of the business portions of the records being omitted.

The thanks of the Society are due to Mr. Geo. S. Strong for the loan of the electrotypes used in illustrating his paper on the "Strong Locomotive;" to the publishers of the *Modern Light and Heat* for those illustrating Mr. Stanley's paper on "Recent Improvements in Systems of Electrical Distribution," and Prof. Anthony's paper on "A Study of Alternating Current Generators and Receivers;" and to Mr. Wm. F. Chester for that illustrating his paper on the "Johnson System of Heat Regulation."

For the opinions advanced by any of the speakers the Society assumes no responsibility.

LINUS FAUNCE,
SECRETARY.

BOSTON, June, 1888.

Erratum.—On page 108, 7th line from top, for 140 read 400.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-SIXTH YEAR.

MEETING 364.

The Arms and Armor of Ancient Japan.

BY MR. TATUI BABA.

The 364th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Oct. 13th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced MR. TATUI BABA, of Tokio, Japan, who read a paper on "The Arms and Armor of Ancient Japan."

Mr. BABA first described the difference between the Japanese and the Chinese, stating that the Japanese were warlike, while the Chinese were a commercial people; that, although they might be of the same race, yet they were very different in their sentiment, language, and art.

The Chinese language is symbolic or hieroglyphic, but the Japanese is syllabic. The Japanese alphabet comprises only forty-seven characters, while the Chinese has not less than five hundred symbols. About the third century the Chinese language was introduced to a considerable extent in Japanese literature, but it was confined wholly to the men; the women, among whom were many noted authoresses, wrote in pure Japanese.

The lecturer next spoke of the differences in the fine arts of the two nations, remarking that, while Japanese art is always the representation of Nature, Chinese art, at least in its later development, is something between drawing and writing. The Chinese, he said, used

to paint well, but, owing to the influence of the learned men of their country, the character of the artists' work changed for the worse, so that now their pictures always require some explanation. Otherwise, people cannot tell whether a certain subject is meant to represent a man or a beast.

Mr. Baba next exhibited a number of bows and arrows. These, he said, were of very ancient origin. Mention is made of them as early as 660 B. C. Yeki, written 500 B. C. by Confucius, says: "A bow is made by bending a tree with a string, and an arrow by straightening its branches; the use of bow and arrows frightens everybody." This weapon has always been considered sacred, and some great generals in olden times are said to have wrought miracles with them. The literature of Japan is filled with legends concerning them.

There are many old bows now carefully preserved in the temples and monasteries of Japan. The oldest, being the one used by the Empress Zingū Kogū, when she made war against the Coreans about 201 A. D., is preserved in the temple of Hachiman in the province of Yamato, near Kioto. It is a wooden rod, slightly bent, with both its ends cut in a shape to fit a string upon; its length is seven feet. The arrows used with this bow are made of bamboo. Great improvements have been made in the construction of bows and arrows since early times, and the former are now made by setting two parallel strips of bamboo in grooves made in the wooden portion of the bow from end to end. These strips were cemented in, and were also held in place by binding with rattan or silk. This difference in binding formed the basis of an elaborate classification of bows.

Mention was made of the hankin or half bow. This is kept in the bedroom as a ready means of protection against intruders, corresponding in its use to our pistol. The strings upon the most ancient must have been made of a variety of tough grass, or perhaps of a certain kind of climbing plants which abound in the mountains. At present they are made of flax hardened by a mixture of pitch and oil. When it is well made and used in a good bow, it produces a clear, ringing sound when struck, which was supposed to be very effective in frightening devils.

The arrows are made of bamboo, tipped with eagle feathers, with steel points. For fighting, a spear-shaped head is used. At present there are about fifty distinct shapes or kinds of arrow-heads

known. The arrows are classified into four groups, according to the use to which they are intended to be put; viz., naya, or hunting arrow; soya, or arrow for the army sent out to attack; sasiya, or arrow for defence; and matoya, or arrow to shoot at a target.

The science of archery reached a high degree of cultivation in Japan, so much so that several distinct schools were formed, each claiming to possess certain secrets unknown to the others. One set of maxims, however, applied to all. These are styled the "ten disadvantages" or conditions under which an archer ought not to shoot: (1) when he is preoccupied; (2) when he is melancholy; (3) when he has been running too fast; (4) when he is intoxicated; (5) when he is hungry; (6) when he has eaten too much; (7) when he is angry; (8) when he is not inclined to shoot; (9) when he is too anxious to shoot; (10) when he is envious of some other archer's skill. The speaker then showed the different methods of handling the bow in shooting.

He next showed a Japanese spear, telling the legend of the god who, standing with a goddess on the floating bridge of heaven, dipped the point of his spear into the water. When he raised it the water from the point froze, and, dropping, formed an island.

The oldest spears now in existence, supposed to date from 672 A. D., have the head about fourteen inches long, and the handle is made of a round piece of wood about five inches in diameter, and a little more than five feet long. During the fourteenth century the spear was lengthened so that the handle was sometimes twenty feet and the head five feet long.

The halberd is not spoken of in Japanese mythology, although it is an old weapon; Japanese history mentions that the Mikado Kozinteno caused the first one to be made, in 770 A. D.

The halberd resembles the spear in possessing a long handle, but differs from it in having a long blade, slightly curved, widening gradually toward the upper end, with an edge at one side only. Its blade is sometimes three or four feet in length, and its handle six or seven feet. It is used in quite a different way from a spear. The mode of holding the latter is always to use the left hand before the right, while that of holding the former is to use the right hand before the left, so as to give facility in cutting as well as thrusting. The handle is used to thrust at the enemy, so that both ends are used

offensively. It is always used in single combat, and when well handled it becomes a very effective weapon. In former times it used to be given to the women to protect themselves with. With some modifications it is used now for fencing. There are some Japanese women in Tokio at present who are very expert in the use of this weapon.

The sword was next spoken of, several being exhibited. He said that it was one of the oldest weapons used for military purposes, and was held in great respect by the Japanese. Some swords have been dug up in the ancient provinces of Japan which date from 200 A. D. Mythological annals relate how, once upon a time, when a god killed a great serpent, and saved a beautiful woman whom the monster was about to devour, he found a sword in its tail. Fencing with swords was taught from an early period.

In conclusion, Mr. Baba explained the construction of three pieces of armor, illustrating the three types prevalent at different times in Japan. The specimen of the oldest type was copied from the model of one worn by the Empress Zingū about 200 A. D., and was called "Haramaki," or "binding corslet." The second, called the "Domaru," or "round corslet," represented the kind used in the fourteenth century, and the third, known as the "Okegawa Do," or "bucket-shaped corslet," that in use in the seventeenth century. Previous to 810 A. D. the armors were made of raw hide ornamented with silk. Since then they have been made of iron and steel.

The different parts of these iron or steel armors were made by horizontal strips of lacquered iron, very closely bound or knit together with ornamented silk cords, so that each part is more or less pliable. These strips are so hung together that the lower edge of one projects under the upper edge of the one immediately below, something after the manner of a window shutter.

The thanks of the Society were extended to Mr. Baba by President Walker for his very interesting lecture, and the meeting was adjourned.

MEETING 365.

An Electrical Apparatus for the Measurement of Water.

BY MR. N. M. LOWE.

The Cosmosphere in Teaching Phenomenal Astronomy.

BY PROF. F. H. BAILEY.

The 365th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Oct. 27th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Mr. N. M. Lowe, who described "An Electrical Apparatus for the Measurement of Water."

Mr. LOWE said that the apparatus was designed to be used in connection with the meter tests which have been in progress for the last five or six months, and that it had served its purpose admirably, causing an undoubted saving to the city of several thousand dollars. The apparatus is arranged so that the short arm of the scale beam breaks an electric circuit when the beam is horizontal, thus releasing a weighted lever which, in falling, shuts a valve, thereby stopping the flow of water, and also stopping a clock.

To test a meter, the clock is set at 12 M., and started the same moment that the valve is open, which starts the flow of water through the meter. This water flows into a tank which is placed on a scale. The scale beam is weighted so as to swing when any definite amount of water has passed through the meter. The swinging of the scale beam, as explained, automatically shuts off the supply of water, stops the clock, and rings a bell. The observer then reads the meter and compares the amount recorded by it with the actual amount passed through as weighed by the scale.

The apparatus was shown in working order, dry sand being used in place of water.

THE COSMOSPHERE IN TEACHING PHENOMENAL ASTRONOMY.

After Mr. Lowe had finished his description, the President introduced Professor F. H. BAILEY, who exhibited and described the cosmosphere, and explained some of its uses in teaching phenomenal astronomy.

He began by saying that he should not discuss the question, where in the school course "Primary Phenomenal Astronomy" should be taught, whether it should precede theoretical, accompany or succeed it; but he would present a few facts of what he termed primary phenomenal astronomy, and illustrate them with the cosmosphere, and then some of a more advanced nature that the instrument would equally well illustrate. Two instruments were used, one being six feet in diameter, which is the only large one yet made, and the school size, which is thirty inches in diameter.

The cosmosphere is a transparent globe representing the celestial sphere. On its surface are representations of the constellations, the positions of stars being indicated by holes in the figures. A circular plane is suspended in the center of the globe in such a manner as to maintain a permanent horizontal position; the margin of the plane represents the observer's horizon, and has indicated upon it the points of the compass. The instrument was correctly adjusted for Boston by placing it so that its axis was parallel with that of the earth. The points of the compass on the margin of the plane then corresponded with those of the horizon. It was set for the correct time by means of a twenty-four hour time dial which surrounds the north pole. The audience was asked to imagine itself in the center of the horizontal plane, and to look from that position and see the stars in their correct position, a thing easy to do with a transparent globe, and as the globe revolved to see illustrated the daily movement of the heavens as seen from Boston. Varying positions of constellations relative to the horizon in rising and setting were pointed out; the Twins were seen to rise in the northeast, lying down parallel with the horizon, but to set in the northwest, standing erect, an astronomical paradox. The axis of the globe was next brought into the plane of the horizon and the movements of the heavens shown, as seen by an observer on the earth's equator, every star in the heavens rising and setting at right angles with the horizon, and being half the time above the horizon and half below.

The spectators were then asked to imagine that they were traveling over the earth from equator to north pole, and to see the variation in the daily motion caused thereby. Then, while the globe was revolving from east to west, it was also revolved through one-fourth of a revolution from north to south around an invisible axis, the poles of which occupied the east and west points of the horizon, the central plane remaining constantly horizontal, thus showing the difference in apparent daily motion as seen from different northern latitudes,—fewer and fewer stars rising and setting as the latitude increases, and those moving nearer and nearer parallel with the horizon, until at the north pole the stars are seen to move from left to right perfectly parallel with the horizon, and not a star ever rising or setting. The latter remark applying to the fixed stars; the seven wandering stars — the "great gods" of the astrologers — would then be seen to rise and set, the sun once a year, the moon once a month, and the other five in varying lengths of time.

Next, the instrument was set again for Boston, and the movements of sun and moon illustrated, as here seen. On the sun's yearly path is marked his position for each day, hence the place and time of his rising and setting and his movement through the heavens for each day are clearly shown. Some of the most puzzling moon phenomena were reproduced and explained with perfect clearness; the reason why the moon sometimes runs high and sometimes low; why the highest full moon is always the one that occurs nearest Dec. 21, and the lowest the one that comes nearest June 21; why the new moon's horns are pointed upwards, "to hold water," in the spring, and so tipped as "to spill water" in the autumn; why the harvest moon when full rises, at this latitude, only half an hour later for several successive nights, but when new an hour and a quarter later.

One of the most interesting and instructive illustrations is that of the varying phenomena of day and night for the different zones. The Professor claims that his experience with schools of all grades has convinced him that but very few pupils of any grade obtain, from the theoretical method in which the subject is taught, anything like clear conceptions of the difference in day and night in the different zones. He has even met teachers of astronomy who have maintained and taught for years such errors as that the sun would be seen,

to a spectator on the equator, to rise exactly in the east and set in the west throughout the entire year. With the instrument set for the equator, days and nights were seen to have a uniform length, but the sun to rise in the east and set in the west no more frequently than when seen from Boston. At the city of Mexico the longest day (June 21) is one hour longer, and the shortest day (Dec. 21) one hour shorter than at Quito. At New Orleans June 21 is fourteen hours day and ten hours night, and Dec. 21 ten hours day and fourteen hours night. At Philadelphia the first is fifteen hours day and nine hours night, and the second the reverse. At St. Petersburg, on June 21, there are nineteen hours between sunrise and sunset, and on Dec. 21 but five hours. At the arctic circle, on June 21, the sun is seen during the entire day, being upon the northern horizon at midnight, but on Dec. 21 he is only seen for a moment directly in the south at midday. At any point on the arctic circle the sun is seen to rise between Dec. 21 and March 20 at varying points along the horizon from south to east, and to set all along the quadrant between south and west; time of rising varying from noon to 6 A. M., and of setting from noon till 6 P. M. Between March 20 and June 21 the sun uses all the quarter from east to north for rising purposes, and from west to north for setting; time varying for rising from 6 A. M. to midnight, and for setting from 6 P. M. to midnight. From the arctic circle to the pole the "midnight sun" is seen an increasing number of nights; at the most northern point of Alaska it is seen continuously for about three months; at Fort Conger, Lady Franklin Bay, for five months, and, finally, at the north pole for six months.

As the cosmosphere has a time-dial attachment it not only illustrates the fact of the varying length of day and night throughout the year for every place on the earth not exactly on the equator or at a pole, shows the exact point on the horizon where the sun rises each day, the exact angle of his path, his apparent movement through the heavens and the point where he sets, but by means of the dial the time of his rising, southing, and setting, either in sun or mean time. Thus the instrument becomes a perpetual almanac, good for all latitudes, giving the time of sun rising and setting very accurately.

As seen from the earth's equator, the sun always rises perpendicular to the horizon, in midsummer about one-fourth way from the

eastern point towards the northern. Each succeeding morning for six months it comes up at six o'clock a little north of its previous point of rising, till in midwinter it rises about one-fourth way from east to south, thus using one-eighth of the horizon for rising purposes; and as it uses the same amount of the horizon for setting, it uses for both a very little more than one-fourth of the horizon. The same parts are used in reverse order during the next six months. The amount of the horizon used by the sun for rising and setting purposes increases from about one-fourth at the equator to three-eighths at Boston, five-eighths at St. Petersburg, and all of it at the arctic circle. All of it is used every alternate three months at Point Barrow, Alaska, and all of it in one month at Fort Conger, followed by five months in which the sun does not rise or set.

The illustration of the pheuomenal movements of the planets were only hinted at for want of time.

The lecturer next took up the subject of the "Precession of the Equinoxes," and showed the changing position of the heavens as seen from Boston during the entire precessional period of nearly twenty-six thousand years. By setting the instrument for the latitude of the Great Pyramid, some of the statements of the "miracle in stone" school of pyramidologists can be verified and others proved false, and the fallacy of the fundamental argument of their theory exposed. Lastly, the movements of the equinoctial points and changing position of the signs relative to the constellations were illustrated and explained.

The instrument is also capable of illustrating apparent movements of sun and stars, as seen from any latitude of Venus, Mars, or Jupiter, consequently the phenomena of day and night as experienced by the inhabitants of any of our planetary neighbors.

The meeting closed with a vote of thanks to the speakers.

MEETING 366.

Hydraulic Cement, Natural and Artificial: Their Comparative Values.

BY MR. U. CUMMINGS.

The 366th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Nov. 10th, at 8 P. M., Prof. Geo. F. Swain in the chair.

After the reading of the records of the previous meeting and the election of new members, the chairman introduced Mr. U. Cummings, of Buffalo, N. Y., who read a paper on "Hydraulic Cement, Natural and Artificial: Their Comparative Values."

Mr. CUMMINGS said: There are two kinds of hydraulic cement, the artificial or so-called Portland, and that produced from natural cement rock. The natural cements were used in all the old engineering works in Europe, while the Portland cements were not manufactured in England till about 1824. The early history of Portland cement is filled with failures and disasters, and it was not until about 1860 that it was used to an extent worth mentioning, and it did not obtain a sound footing until about 1874. There had been but little done in the way of tensile strain tests until 1858. It was discovered soon that the artificial cements would, if well manufactured, sustain a higher tensile strain than the natural brands, and this naturally and rapidly led to a belief in their superiority.

All hydraulic cements, whether natural or artificial, are produced by a mixture of clay and carbonate of lime, or lime and magnesia. These two ingredients are usually mixed together in a pug mill with a free use of water. Sometimes they are ground together in a comparatively dry state. But in either method the quality of the cement depends greatly on the thorough admixture of the two materials,— it being more important even than a proper combining proportion, although the latter is essential to the production of a first-class cement. After these materials are incorporated into a homogeneous mass, it is dried and made into blocks and placed in suitable kilns for calcination. The preliminary operation in calcination is the expulsion of moisture, which is soon followed by the car-

bonic acid contained in the carbonate of lime. Then a chemical reaction takes place. Under a high temperature, the lime rendered caustic by the expulsion of the carbonic acid and in intimate contact with the silicate of alumina, the latter is decomposed, and a new combination is formed, known as silicate of lime and alumina. If magnesia be present, then a triple silicate of lime, magnesia, and alumina is formed.

In a Portland cement each atom of silicate of alumina must come in close contact with its equivalent of lime carbonate. A failure in this regard will result in the production of a cement that will heat, check, and expand, thus showing the presence of free or caustic lime or free clay, and no amount of subsequent grinding or mixing will change these conditions.

[The speaker quoted from Henry Reid's work on Portland cement, to show that its manufacture will be attended with a danger that must ever be constant so long as the matter of mixing is entrusted to human hands.]

While Nature did not always deposit her natural cement rock formations in true combining proportions, no handicraft has ever yet excelled or even approached her in the art of mechanical combinations of clay and carbonate of lime, for with natural cements, however much the proportions of ingredients may vary, as between the upper and lower layers there is usually a large percentage of the bed that is so well proportioned as to yield a good cement when all are mixed together; and even the layers that are not well proportioned, owing to their finely commingled condition, are not as dangerous an element in the mass as is that of an equal amount of an imperfect mixture in an artificial cement. As a rule, the lower layers contain more clay than those above, the proportion of clay gradually diminishing and that of carbonate of lime increasing as we ascend in the series of layers. This variation in proportion in the several layers amounts in some deposits to twenty per cent, and so it may be seen that although the cement produced from such deposits may after a thorough mixing, first in the kiln and then in the grinding, exhibit by analysis a cement made up of very fair proportions, it also shows that it is not impossible to find that a cement may be heavily overclayed and still contain free or caustic lime; and it must be seen that although the proportions may be correct, yet the percentage of true

silicates cannot be predicated on such analysis, for the reason that two distinct layers of diverse proportional ingredients, when placed together in a kiln, cannot form a chemical combination, the excess of clay in one fragment of rock cannot combine with the excess of lime in another. Fortunately, excessive variations are rarely to be met with, but it is to these facts alone that may be attributed about all the superiority that can reasonably be claimed for an artificial cement over the natural. And even in this regard the difference is not great on account of the unknown and doubtfully ascertained quantity of moisture in the chalk and clay, varying in the former from 10 to 25 per cent, and in the latter from 25 to 60 per cent.

It is also possible to adulterate Portland cement, and, according to the printed reports of the transactions of the Association of German Portland Cement-makers, adulteration with slag and other similar materials is carried on by some of the manufacturers to an alarming extent. The maker of natural cements has no occasion to adulterate, as there is no material he could use which is as cheap as the cement rock.

The natural cement rock formations are well distributed throughout the country. They are known to exist in twenty-four of the States, and the supply is practically inexhaustible. There are now upwards of fifty manufactories in the United States, with an output the present year of nearly seven million barrels. This is the best of evidence that the quality has been universally good.

Over eighty per cent of the cement manufactured in this country contains magnesia in proportions varying from five to twenty per cent. The artificial cements contain little or no magnesia. It is claimed by the manufacturers of this grade that a first-class cement cannot be produced with magnesia as one of the bases; but there are many high authorities who dispute this proposition, and especially among the French engineers; and as to our experience among the natural cements of this country, we find the magnesia cements among the earliest manufactured, and the consumption of upwards of fifty million barrels of this class, used in the construction of the great engineering works of this country, is sufficient to establish the fact that the triple silicates are equally as durable as the double.

[Mr. Cummings next discussed the combining proportions of the three bases, and the different theories as to the formation of the sili-

cates, and showed that silicates are formed during calcination, and not by the action of water afterward.]

It is an error to suppose that the natural cements of this country are all about alike, and that the testing machine will very quickly tell us whatever differences may exist. It is surprising how widely some of our natural cements may vary from the correct standard of proportions and yet sustain a high tensile strain, and be acceptable to the consumer. A well balanced cement will withstand the action of frost many years, while an overclayed one, whether natural or artificial, will not, and of this the testing machine gives no indication. If we take two cements, one being natural and the other artificial, and so nearly alike in composition that a chemist could not distinguish between them, the artificial will test higher than the natural product, but can it be truthfully maintained that it is the better of the two? If we are governed by prevailing public opinion we must admit it, for the testing machine says so. Had the chemistry of cement and the laws governing combining proportions been made more of a study in the past, we should not now see the whole question submitted to this crucial test called tensile strain.

The testing machine came into use about 1860, and the Portland cements came to be considered as better than the natural because they would stand a higher tensile strain. If the Portlands were superior, it is a little strange that such engineers as Grant, Colson, Mann, and others had not discovered it in all the years prior to 1860; although it may be urged that they were confronted with the excellent work done with natural cements, in the construction of the railway tunnels, the heavy stone arches and deep foundations done during the earlier day; there was the great Thames tunnel, commenced in 1807 and completed in 1843, every stone of which was laid in natural cement, and stands today in all its perfectness, a powerful argument in favor of natural cement. But the tensile strain fever had set in, and men argued then as now that, if one cement sustains a higher tensile strain than another, it must be better, because it is stronger. And this argument seems unanswerable, and, coupled with the fact that it is a quick and ready means by which the engineer may draw conclusions, has been the cause of its adoption to such an extent that today the engineer who does not have access to a testing machine is considered behind the times.

Looking at this question from the standpoint of one who has had over thirty years of practical experience in the manufacture of cement, witnessing the entire rise and growth of this modern giant, the testing machine, always ready to adopt any and everything looking to an improvement in the quality of hydraulic cement, studying the action of all the leading brands in the market under varying circumstances, and devoting much time to the deeply interesting study of endeavoring to find the connecting link that ought to exist between high tensile test and first quality, and oftentimes seeing a cement that was notoriously overclayed test one hundred pounds to the square inch, while another cement, nearly perfect in its composition, testing barely sixty pounds, and the resident engineer deciding unhesitatingly in favor of the higher testing brand, without a thought as to the question of analysis and combining proportions and all that goes to render a cement capable of withstanding the changes incident to this trying climate, with its extremes of heat and cold, we have sometimes been forcibly reminded of the old adage that "a little knowledge is a dangerous thing." During the last summer a professor of high repute in one of our leading colleges condemned outright one of the best natural cements I ever knew,—a cement that had been thoroughly tried in the construction of masonry in bridge piers, where the current was so powerful and the flow of ice in the spring so terrible that the late Colonel Eads declared that no bridge piers could be built to withstand the shock. I mention this to illustrate the working of the testing machine. If it can deceive a professor in one of our foremost colleges, who can it not deceive?

In our search for the connecting link that, as we have said, ought to exist between high tensile strain and first quality we have traveled up and down the whole line, commencing with fifty per cent clay and fifty per cent lime, and following along up through its varying mixtures until pure white lime, with no clay, is reached. These we have studied under every conceivable manner of manufacture and subsequent manipulation, studying the varying proportions with all their bewildering and mystifying contradictions, plodding through the many phases that are continually being developed in the course of a long experience in the study of the natural cements of this country, searching the tables of tests made by prominent engineers from time to time, comparing the tables with analyses of the brands

tested, weighing carefully every feature that gives the slightest promise of throwing light on the subject, and now, after all these years, we are compelled to admit that we have not been able to discover the slightest relationship between high test and good quality. Practical experience teaches that we can find both good and bad cements that will test high, and good and bad cements that will test low. A cement may be so overclayed that in a barrel of 300 pounds there may be but 225 pounds of silicates or active setting matter, yet I have seen such cements test as high as 100 pounds in twenty-four hours. Such cements, when slightly underburned, behave very well in air or water, the free clay acting as a pozzuolana; excessive heat, however, greatly impairs or destroys the silicates, and if carried to a high point the resultant cement becomes inert. With our present modes of burning there will be variations beyond the control of the burner, caused by changes in the direction and velocity of the wind. Yet such changes have but little effect on cements containing an excess of lime (not exceeding five per cent). Such cements will sustain a high temperature in the kiln and be benefited thereby. If it becomes a question to decide which cement to choose, one containing an excess of clay or lime, we must unhesitatingly choose the latter. This is contrary to the prevailing belief; yet, if we accept the teachings of time, it must be conceded. The overclayed brands are at their best when fresh, while those containing an excess of lime require age to allow a thorough hydration of the free lime by exposure to bring out their best qualities. They will withstand the action of water equally as well as the overclayed brands, and for all masonry above water, or where subjected to water and air alternately, are infinitely superior. If properly hydrated, such cements will sustain immediate immersion even better than the overclayed brands, and will test equally as high; yet the fracture will show that crystallization has hardly set in at twenty-four hours, as they will yield readily to the knife, while the overclayed varieties show a much harder set, thus disproving the idea so prevalent that overlimed cements set quicker than the others. The setting of a cement becomes slower as the proportion of lime is increased, until we pass up through the slow-setting hydraulic limes and arrive at the pure limes where crystallization ceases. We must remember that that which causes a cement to set promptly under water is also the cause

of its comparatively early disintegration when exposed to the atmosphere. A cement that carries so much lime as to require from three to six months to harden in exposed masonry will be found in perfect condition ages after the mortar made from quick-setting cements has crumbled out and disappeared.

The Aberthaw hydraulic lime, consisting of 81.16 per cent of lime and 18.84 per cent of clay, the lime containing 62 per cent of silicate of lime and 38 per cent of free or caustic lime, was used in the construction of the Eddystone Lighthouse in 1757. It was so slow in setting that the engineer, Mr. John Smeaton, of England, covered the joints with plaster of Paris to protect them from the sea until the mortar hardened. This lighthouse stood in perfect condition over one hundred years, and until taken down to make way for a larger one. The hydraulic lime of Teil, in France, the composition of which is substantially the same as the Aberthaw lime, has been in use in the form of concrete made into blocks for sea walls for the past fifty-five years without showing any signs of disintegration. Neither of these limes can be made to test ten pounds in twenty-four hours if given but one hour in air, and they would stand a poor show in this country where quality is gauged by the testing machine. We have in the United States inexhaustible beds of hydraulic limestone, equal in every respect to those just mentioned, which probably will be utilized to only a limited extent so long as the present conditions as regards high test exists.

Any coloring matter is an adulteration, the amount usually found, however, is of slight importance. A dark cement may or may not be a good one. A prejudice in favor of any particular color disappears when we come to learn that a really perfect cement would be white.

Portland cement has not been in use in this country long enough to earn the position it now occupies, but, owing to some peculiarity in its molecular construction, it will test higher than our American cements and will get harder, yet hardness is no evidence of durability. With equal exposure, a flint stone will disintegrate much more rapidly than a soft magnesian limestone. But the demand at present is for high test, and he would be a rash man indeed who would dare to stand against it. The manufacturer of a first-class American cement, looking back over the marvelous engineering works of the past which

have consumed upwards of seventy-five million barrels of natural cement, all manufactured in this country, and none requiring renewal on account of the poor quality of the cement used, are yet daily reminded that their cement is only a cheap article.

The testing machine is a good thing if put to a legitimate use. It is the abuse of it that we object to. It should occupy a subordinate place. The understanding of the proper use of the machine consists in knowing something of the chemistry of a cement, in knowing what a table of analysis means, in having a knowledge of true combining proportions, and of the effect of variations therefrom. Then the testing machine becomes a valuable auxiliary, for its readings have taken on a new meaning.

A study of the tables of long-time tests of Portland cements as compiled by such engineers as Clarke, of Boston, and MacClay, of New York, and others eminent in the profession reveals the fact that briquettes of neat Portland cement do not test as high at three or four years as they do at one or two years old. I have seen works that were made with Portland cement concrete remain in perfect condition for eight years, and during the ninth year go all to pieces. The ten-year tests of Portland cement made by Dr. Michaelis, of Berlin, show that the maximum strength was reached at the end of two years, and this point held fairly well until the end of the seventh year, but from that time until the end of the tenth year there was a remarkable falling off in values.

During the past summer the engineer in charge of the Aberdeen harbor sea works reported a serious failure in the Portland cement concrete works at that point. After only fifteen years' immersion it went to pieces, while the natural cement concrete, at the same place and the same age, was in good condition. After a thorough examination by a board of engineers, assisted by Professor Brazier of Aberdeen University, it was concluded that "Portland cement cannot resist the action of sea water." Another case is that at the harbor of Dundee, reported upon during the past summer. In this instance the Portland cement concrete had softened in sea water, and natural cement was used to protect it if possible from further disaster.

The investigations of Professor Tetmajér, of the Federal Polytechnical School, at Zurich, developed some interesting information. It has long been noticed in Germany that Portland cement of certain

kinds, when exposed for several years to the air, loses its consistency and crumbles.

This danger had become so serious that the German Minister of Public Works issued a circular in 1885, restricting, within narrow limits, the use of Portland cement in work exposed to the air.

Since that time Prof. Tetmajér has devoted himself to investigating this matter, and, according to his statements, the cause of the disintegration of Portland cement exposed to air is to be found in a want of proper preparation of the materials, particularly in the lack of sufficient grinding together of the chalk and clay to ensure the complete silification of the lime during the process of calcination.

But the best brands of Portland cement, which had withstood the action of water for several years, became soft on exposure to air. He says, also, that "air especially attacks sharply (heavy) burnt cements, which imbibe a great deal of carbonic acid, and the decay in water is caused by an excess of matters which undergo an increase in volume by oxidation and imbibing of water."

The Professor found about 10 per cent of the brands tested in this condition.

In the light of this exposition of the characteristics of both, the English and German Portland cements, in the countries where they are manufactured and where they have been the longest in use, it would seem that no other or better evidence is needed to prove that artificially made cements, however high they may test, are not true cements, and the people of this country who, of late years, are using Portland cements with such unlimited confidence in the superiority of those brands over our own natural cements, a confidence born of the testing machine and nurtured in the belief that tensile strain can be as unerringly applied to cements as to iron or steel, may yet awaken to a sad realization of the deceptive character of such tests, for it may well be predicted that in a very few years we shall see evidences of disintegration and decay in many of the important works now being constructed of Portland cement in this country.

Comparing these things with the splendid record made by the natural cements used under similar circumstances, that have successfully withstood the chemical action of the sea water for over half a century, we are led to the conclusion that man has not yet succeeded in compounding the materials essential to the production of a first-

class cement that can surpass in durability that which nature has so bountifully bestowed upon us.

An interesting and lengthy discussion followed the reading of the paper, after which the meeting adjourned with a vote of thanks to the speaker.

MEETING 367.

The Strong Locomotive.

BY MR. GEORGE S. STRONG.

The 367th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Dec. 8th, at 8 P. M., Mr. C. J. H. Woodbury in the chair.

After the reading of the records of the previous meeting, the chairman introduced Mr. George S. Strong, of New York, who read a paper on "The Strong Locomotive."

MR. STRONG said: The Strong locomotive is the result of a determination to overcome the chief defects in the ordinary locomotive without, at the same time, introducing any radical differences of principle or general appearance, and it is generally conceded that the two main defective parts of a locomotive are the boiler and the valve gear. The demand now is for high speeds, and it is certain that the long distances to be traveled in America require a high speed service more than the short runs in England.

First, the boiler. It is by no means impossible, with a rectangular fire box, to obtain as large a fire grate as may be desired, but this is done at the expense of safety. The flat-sided box, with its multitude of screw stays, is not a scientific form of construction, but one which contains the elements of self-destruction, as the thousands of broken stays constantly testify. Hence, as regards the boiler, there is required some structure providing a larger grate area than hitherto has been safely employed, and constructed on recognized safe and scientific principles. Modern practice calls also for higher pressures,

and for such high pressure any boiler to be a success must be safely suitable. A flat surface exposed to pressure is the very worst form in which material can be disposed, and stays are thus simply an expedient for holding up to their work surfaces of metal which ought not to be found in a steam boiler, for in a flat surface the stresses are transverse, and a thin plate is as unsuited to resist a transverse stress as is a very shallow truss to carry a great weight. Deflection must take place, and to prevent this the stays are employed, and add very greatly to the weight of the boiler, as well as to its cost, and after all are but an unscientific make-shift.

Secondly, the valve gear. Now, supposing that a full supply of steam is available from the boiler, it is impossible to obtain the power from the engine which could be obtained from, say, a Corliss engine, at equal speed and steam pressure; when at high speed, and with steam blowing at the safety valves, there appears to be something which holds back the engine. It is not the slipping of the wheels, for it is not found that wheels do slip at high speeds. It is not that the cut-off in the cylinder is too early or too late, for any variation from a certain position of the reverse lever only lessens the speed. The fault is one that is inherent in the common link motion, namely, excessive compression. The great evil of excessive compression is the enormous reduction which it makes in the power of the locomotive at high speed. Deprived of perhaps a third or more of its proper tractive power, the engine cannot attain a high speed with a heavy load.

Quite apart from the question of small consumption of coal per horse power is the question of the general efficiency of a locomotive. If an engine is sufficiently heavy to start a certain train from rest and draw it at a moderate speed, it may have a mean cylinder pressure at late cut-off about equal to its adhesion on the rail. At a high speed, however, the adhesion of the engine is very much in excess of the cylinder tractive power, and hence a great amount of useless weight has to be transported. If, however, the cylinder traction be doubled by an improvement in the valve gear, we should still at high speeds have a sufficient adhesion to draw double the load, and we should still haul with one engine and two men a load which would pay double freightage for the same wage expenditure. It is apparent, then, that we may lose more by striving after economy of

fuel per horse power than by seeking to increase the tractive power at speed per pound weight of machinery. The question of efficiency per pound weight of motor has been far too little studied, and it is acknowledged that an engine which secures a high efficiency, and does so without loss of economy, is a machine worth some consideration, and such is the Strong locomotive.

To run a heavy train at high speed requires a large power, and this implies a high mean cylinder pressure and a continuous and well sustained steam supply, which are not obtained by the ordinary valve gear and rectangular fire box, but have been obtained in the Strong locomotive. Within the fire box shell are two furnaces which together give a grate surface about three times that of ordinary locomotives. The large area of grate renders possible a lighter blast, so that the fire is not torn up. Beyond the furnaces is a separate combustion chamber, in which combustion is completed before the gases are quenched in the small tubes.

The furnaces are of the type successfully introduced by Mr. Samson Fox of the Leeds Forge Company in 1878, and so largely used in marine practice. They are of steel, corrugated, so as to form a series of compound arches giving immense resistance against a collapsing pressure when rolled into cylinders, and are, for all practical purposes, indestructible, having been found capable of resisting a collapsing pressure of 1100 pounds per square inch. Hitherto the weakest, a locomotive fire box may now be made the strongest part of the boiler. The furnaces are united by a junction piece, or "breeches," to the combustion chamber, also of corrugated steel. The riveted junctions lying in the path of the flame from the fires are Adamson flanged seams, a form which provides that no rivet shall be exposed to the action of the fire, and is now in almost universal use in English boiler practice. We have in this boiler endeavored to avoid all transverse stress, and trusted to the direct tensile and compression strength of the material. The barrel of the boiler, being like the furnace and combustion chamber welded at all longitudinal seams, presents no material points of difference from the ordinary boiler, but back of the barrel the difference is very great. In place of the flat-sided fire-box shell, with circular top, we have two segmental pieces joined by a stout central or division plate. Each segmental half of this shell acts, therefore, just as though it were a

complete circular shell, for the division plate has, of course, pressure on both sides, and acts by tension only to resist the bursting stress on the cylindrical segments. The welding of the longitudinal seams has been made possible by the introduction of gas for such purposes, which enables us to heat up the welding scarfs to the proper temperature and preserve their surfaces clear and free from dirt, oxidation, or anything which might tend to make the weld less reliable than the rest of a plate. By welding, too, we may have perfectly circular barrels not otherwise obtainable without butt jointing and double covers, and so we avoid any tendency to grooving.

The back head is the only portion, except the tube plate already referred to, that is exposed to pressure and yet flat. As, however, it is chiefly occupied by the furnaces, this is of small account, and a slight gusset stiffening is all that is required as staying, and forms with similar staying of the front tube plate all the staying in the boiler. As now constructed, every part of the boiler may be machine riveted. It is thus seen that we have a boiler fully capable of supplying all the steam required from it, and the only remaining problem is to devise an engine to suitably utilize this steam.

As before mentioned, the old link motion does not meet the requirements. It is desirable in a valve motion to avoid sliding parts, and secure pin joints only. It is desirable also that the waste spaces or clearances in the cylinders be as small as is consistent with due area of ports and passages. Modern steam engineering demands not only separate valves for steam and exhaust, but also independent regulation of exhaust valves.

The problem, then, was to design a valve gear in which the steam and exhaust valves shall be moved separately, so that full advantage might be taken of the benefits of both cut-off and moderate compression. These requirements have been fully attained in the gear adopted. In place of a single slide valve, four valves, all alike, are employed for each cylinder, two for steam and two for exhaust. They are of the gridiron, or multiported type, and work up and down when in full gear only $1\frac{1}{16}$ inches vertically. The actuating gear consists, for each cylinder, of a single eccentric only, to the strap of which are attached the two eccentric rods. One of these, for steam valves, is rigidly attached to the straps; the other, for the exhaust, is pin-jointed. Each rod is suspended at a point

eight inches from its extremity by a long link to a block, which slides upon a quadrant. Each block may be placed at any desired position on its quadrant by means of the reversing levers, and so decide the point of cut-off, and whether the engine shall run forward or backward. From the eccentric rod ends motion is taken through the connecting link and bell crank arm and horizontal rod to the valve levers or rockers. The result of this peculiar arrangement is to give a rapid opening and closing of the steam and exhaust ports, and to cause each valve to stand almost still during half of each revolution of the eccentric. The gear is very simple and readily comprehended. It has no working parts other than cylindrical pin joints, and therefore works with a minimum of wear and tear.

The seats in which the valves work are turned cylindrical plugs which fit in bored chambers cast in the saddle of the cylinder in place of the usual steam chest. Suitable grooves are cut or milled out in the seats and arranged to fit the valves. In each valve of a 20 x 24 or 19 x 24 inch cylinder are 10 ports, each 4⅝" long by ¾" wide. The steam edge is, therefore, 46¼ inches long, or nearly three times that of an ordinary valve. By this long admission edge the initial cylinder pressure very closely approaches that in the boiler, and the rapid opening of the port and equally rapidly closing insure that the initial pressure shall be well maintained and cut-off sharply defined. The same applies to the exhaust also, which may be kept open until just such point as will give a proper, but not excessive, compression. An ordinary locomotive at early cut-off loses about a third of its proper mean effective pressure, from excessive compression, and this necessitates a later cut-off, and, perhaps, a threefold expansion only, in order to maintain the mean pressure we secure at a sixfold expansion.

We are thus enabled to obtain a greater tractive force per pound weight of engine, and instead of, as now, an engine being far too heavy for its work at high speeds, we are able to more fully utilize such weight by the conveyance of a greater load at equal expansion. (Various indicator cards were shown from a Lehigh Valley engine with the Strong valve gear, and from an engine of the Lehigh Valley road which is a good example of a link-motion engine, showing differences in favor of the former.) Generally, it may be said that wheel diameters are too small in America, and it is an advantage of

the Strong valve gear that the addition to the area of indicator diagram due to the reduction of the compression enables us to obtain an equal tractive force for the same cylinder with larger wheels than in an ordinary type of engine. While we would not advocate the over cylindering of an engine, we would point out that for economical working a cylinder must be of a diameter sufficient to allow of the steam being pretty well expanded. Too frequently engineers will run with half-closed throttle, and in almost full gear, rather than employ the reversing lever for expansive working, and a probable cause of this may be the poor exhaust given by the link motion. With separate exhaust valves, which can be set to full travel at all times, there is no excuse for using the throttle, which must always be thrown wide open, and all regulation effected by expansion only up to six expansions, beyond which further regulation may be made with the exhaust lever. The importance is shown, too, of reducing the general back pressure line down as closely to the atmospheric pressure as possible. To this end it is not merely requisite that the exhaust valve should have its full travel for all grades of expansion, but also that the blast nozzle should be as large as possible, consistent with steam raising, and the larger the fire box the more gentle may be the blast within reasonable limits.

The highest power ever obtained from a locomotive hitherto has been 1200 horse power. No. 444 (Strong locomotive) of the Lehigh Valley Railroad, when ran on the Northern Pacific road, on the 24th of June last, pulled 12 cars a distance of 10.8 miles in 11 minutes, from a dead stop to a dead stop. The weight of train was 370 tons, exclusive of engine and tender, and with a boiler pressure of 160 pounds. Cards taken at a speed of 326 revolutions per minute show no less than 1810 horse power,— an unprecedented result. No. 444 has 6 coupled wheels of 62 inches diameter, carrying 90,000 pounds on the drivers, with 27,000 pounds on a four-wheeled front truck and 20,000 on a two-wheeled rear truck. Her total wheel base is 30¼ feet, but the rigid base is only 5 feet 7 inches, the leading driver having a seven-inch blank tire, so that with swing-motion to both trucks she can pass curves of 200 feet radius. The grate surface is 62 square feet, and there are 1848 feet of heating surface. With this the engine makes ample steam from the finest buckwheat coal or screenings to take the heaviest trains up 96-foot grades, and does the

work hitherto never done, except by two locomotives. It will haul twenty cars at sixty miles speed on a level, and keep it up. For fast work, however, larger wheels than 62 inches are to be preferred.

The plates herewith show clearly the various details of the locomotive.

The meeting was adjourned, with a vote of thanks to the speaker for his very instructive paper.

MEETING 368.

Recent Improvements in Systems of Electrical Distribution.

BY MR. WILLIAM STANLEY, JR.

The 368th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Dec. 22nd, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting and the election of new members, the President introduced Mr. William Stanley, Jr., Electrician of the Westinghouse Electric Light Co., of Pittsburgh, who read a paper on "Recent Improvements in Systems of Electrical Distribution."

Mr. STANLEY first gave a brief account of the early history of electrical development, alluding to the efforts of Sir William Siemens of England and Mr. Charles F. Brush of our own country in 1870. To the latter gentleman we are indebted for the practical development of the series of arc systems of lighting. Following closely upon the introduction of the arc light came the development of the incandescent lamp by Sawyer and Edison of this country and Swan of England.

Small wires were at first used, and they were gradually changed to larger ones until the cost of these conductors became a matter of most serious consequence; amounting, in fact, to the prohibition of

the electric light as a general illuminant until a solution for the difficulty was found.

The speaker next showed that it is possible to make the pressure applied to a circuit high or low, and transmit a given amount of electrical energy, providing we always vary the quantity of electricity inversely as we change the pressure, so that the product of the two is always the same. Also, that in delivering a given amount of electrical energy over a circuit of given resistance the loss, or waste in the conductor, will be inversely as the square of the pressure. Electrical engineers, therefore, have endeavored to devise a high-pressure system to distribute electrical energy, because of the attending economy. But it has been nearly impossible to construct economical incandescent lamps requiring a higher pressure than 100 volts, hence the pressure on the mains was originally limited to this value.

Mr. Stanley said that he had roughly calculated the size of a conductor (of which there are two) requisite to transmit the current for 10,000 incandescent lamps, at a pressure of 100 volts, over a distance of 3000 feet, with a maximum loss of five per cent in the conductor, to be nearly as large as a man's body, and that the cost for the 3000 feet, double, is $316,202.

Continuing, Mr. Stanley said: It is evident that the series system is the most economical in cost of conductor, as the same sized wire will answer for any number of lights. This system of connection, however, is unfit for the general distribution of electricity on account of the very great potential necessarily applied to its terminals, and the impossibility of extinguishing lamps without affecting the brilliancy of those remaining in circuit.

The multiple arc system at low potential, while it affords the greatest flexibility and self-regulation for varied currents, is incompetent to fulfill the requirements of a system of general distribution on account of the enormous cost of the mains.

Mr. Brush devised two modifications of these systems,— the one called Series Multiple, the other Multiple Series. They are a combination of the Series and Multiple Systems.

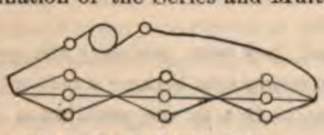


Fig. 1. Brush Multiple Series.

Here a constant quantity of current from the dynamos is led to a bunch of lamps connected in multiple arc to one another, and in series with other bunches or groups. The

difference of potential, or E. M. F., in this particular case is 300 volts. The weight or cost of conductor for a given distance relative to the weight and cost of a conductor for the same number of lights at 100 volts, and with the same percentage of loss, would be inversely as the square of 100 is to the square of 300, that is, inversely as 10,000 is to 90,000, or directly as 9 is to 1. So that this conductor would cost one-ninth of the conductor for 100 volts.

This system, however, possesses the disadvantages incident to series distribution.

The other system of Brush is the Series Multiple.

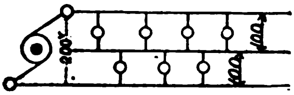


Fig. 2. Brush Series Multiple.

In this particular case the difference of potential is 200 volts. This system is admirable in comparison with anything already described. It is practically a multiple arc 200-volt system, requiring one-fourth the quantity of copper used with the 100-volt distribution. So long as the number of lamps on each side of the center wire is equal, it works perfectly, but as this is rarely the case, means must be provided for compensating for the excess of current upon the side having the lesser number of lamps in circuit. Mr. Edison has designed a very simple and beautiful arrangement for this purpose.

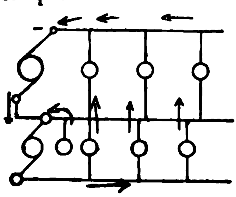


Fig. 3. Edison 3-Wire System.

Here two dynamos, each of 100 volts, are connected in series; the two outside terminals are connected to the two principal mains, and the center connection between the dynamos is attached to the middle or third wire. The excess of current on one side over the current on the other side returns by the third wire to its generating dynamo, as indicated by the arrows. The cost of the conductors, relative to the 100-volt distribution, is, for the two outside mains, 25 per cent, and for the center main about 15 per cent, or 40 per cent in all, of the 100-volt distribution. So that the saving by the Edison three-wire system amounts to 60 per cent on 100-volt distribution.

The copper for 10,000 lamps, Edison three-wire system, at 3000 feet, with a maximum loss of 5 per cent in mains, would cost then about $126,480, which is still quite a considerable item.

We will now turn our attention to the results of the endeavors

of other engineers who have attacked the distribution problem from another standpoint, bringing an entirely new class of apparatus to bear on the subject. And I must here ask your indulgence for digressing.

The induction coil has slumbered through more than fifty years. Born of the genius of Faraday, its phenomena attracted the attention of the scientists of the world in its infancy; but, excepting for exhibiting phenomena *in vacuo*, and as the tool of the physician, little work of importance has been assigned to it through all these years. About 1879 the possibility of utilizing the inductive effects of currents upon one another for the purpose of economically changing the potential from a greater to a lesser value, or *vice versa*, and utilizing the induction coil for this purpose, in a system of distribution, presented itself to a number of investigators. In Europe Messrs. Goulard and Gibbs endeavored to apply the conception. In this country Prof. Elihu Thompson, among others, clearly appreciated its usefulness. In 1881 I myself used an alternating current and induction coil for transforming E. M. F. from a higher to a lower potential, and ran incandescent lamps from the secondary coil; but it was not until in London Messrs. Goulard and Gibbs attempted to operate a central station by means of alternating dynamos and induction coils attached in a series arrangement that the true value of the induction system became known. The arrangement of apparatus chosen by Goulard and Gibbs was most unfortunate. The series system of arrangement is not adapted to flexibility. The design and construction of their induction coils was unworthy of the subject, and inferior to the first coil of Faraday; but their persistent attempts at commercial results are deserving of our gratitude. In 1883 Rankin Kennedy, of Glasgow, in a note to an electrical journal, indicated vaguely the advantages to be attained by arranging the induction coils in parallel. Shortly after Messrs. Zipernowsky and Deri of Pesth designed an induction system on the lines indicated by Kennedy, which, at the time, was a great advance in the art.

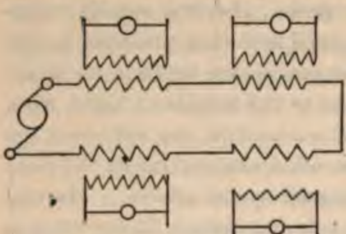


Fig. 4. Goulard & Gibbs System.

In the spring of 1885, at the request of Mr. Westinghouse, of Pittsburgh, I began to look into the possibilities of the induction system. Naturally, I tried a series arrangement at first, but found the difficulties above mentioned. This work, however, bore as a result a clear conception of the counter effects occurring in the induction coil, and eventually pointed out the way to construct the system now in use in this country, which I shall have the honor to describe to you this evening.

The induction system of the Westinghouse Electric Company consists of an alternating current dynamo, constructed to develop an approximately constant E. M. F. of 1000 volts; also of means for exciting the field magnets, and for properly regulating the E. M. F. of current and potential indicators, to guide the attendant in charge of the dynamo; besides a multiplicity of station details which, although apparently unimportant, are necessary to the proper equipment of a central station; but the particular feature of this system, which distinguishes it from previous systems of high potential distribution, is the induction coil or converter, as I have called it. Induction, or the development of an E. M. F. without contact, occurs through the instrumentality of a magnetic field of force,—that is, the field is the vehicle of the induced E. M. F. It is necessary to cause a variable relation to exist between the field and the conductor in order to develop an E. M. F. on it. A magnetic field of force is supposed to consist of magnetic lines of force,—the strength of the field being proportional to the number of lines. These lines of force surround a conductor, and it has been discovered that, if the number of these lines can be varied about a conductor, an E. M. F. will be developed on it proportional to the rate of variation in the number of lines; thus, if we have two conductors side by side, the one connected to a dynamo whose current varies, we will induce an E. M. F. upon the neighboring wire. An apparatus thus constructed is called an induction coil.

The best induction coil—that is, the one in which the loss through induction is least—is a coil in which every line of force surrounding the conductor in which it is developed also surrounds every other conductor upon which it is to impress its E. M. F.

There have been many designs of induction coils, but the best ones are very much alike. In the Westinghouse Electric Company's

system we wind the primary and secondary coils of wire on forms, slip them off, and place them side by side. We next place around them these thin sheets of iron passing the projecting teeth through between the coils.

In this way the coil is built up until it is filled with the iron plates. It is then placed under an hydraulic press, and when pressed tightly together is confined by bolts and a framework. Coils to be used out doors are encased in an iron box which also provides for the fusible safety devices.

These coils are proportioned so as to reduce the E. M. F. from 1000 to 50 volts,— that is, the ratio 20 to 1.

The cost of the conductors with this system relative to the cost at one hundred volts pressure is 1-100, the saving being 99-100. Thus, the copper conductor for 10,000 lamps distributed over 3000 feet distance, with a loss of five per cent, would cost with this system $3162 against $316,202 for the 100-volt system. To this must be added the cost of the converters necessary to transform this amount of current, which, at present prices, is $30,000, making a total cost for this system of $33,162. The cost of copper conductor for the 200-volt Edison three-wire system under the same conditions would be $126,634, — that is, the cost in the case of distribution by the induction system, at present prices, is about one-quarter of a 200-volt three-wire system.

I do not present these figures as limiting either the three-wire or the induction system; but to indicate the commercial relations now existing. You will notice that the item of $30,000 for converters is constant; that is, it does not increase with the distance covered. From this it is evident that as the cost of the mains, with a constant percentage of loss, increases as the square of the distance, there will be found a limit of equality of cost between these systems, which limit will be a given distance from the dynamo. True for but one per cent of loss, or the cost of the conductor in these systems will be equal at different distances for different numbers of lights at different per cent of loss in the mains. The greater the area of distribution, the greater the number of lamps to be distributed, the greater the economy of the induction system. On the other hand, in many cases at short distances the three-wire system is the most economical, thus: for 500 lights at a distance of 300 feet, with

a loss of two per cent, the cost of main for the three-wire system would be $156, while for the induction system it would be $3.60, to which must be added the cost of converters, $1500, making a total of $1503.60.

For large central stations with the induction system, we may neglect the cost of conductors, and compare only the cost of the converters with the cost of mains of any direct current system yet devised; and it is in this branch of electric lighting that the distribution by means of converters is an advance over any other system now in use.

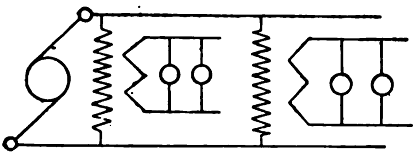


Fig. 5. Westinghouse System.

In the Westinghouse Electric Company's system, the dynamos are run at such a speed as to give about 16,000 alternations per minute, or about 266 alternations per second. With this number of alternations, the loss in conversion, other than that due to the current overcoming the resistance of the primary and secondary wires, is very small. There is unquestionably a loss due to simple magnetization and de-magnetization of the iron core, but it is so small as not to enter into the calculations on converters.

I have noted a few cases of the cost of distribution between the two principal systems now in use in this country.

Edison "3 wire" 200 Volt System				1000 Volt Induction System.		
Per ct. of loss in Mains.	Distance.	No. of Lamps.	Cost of Mains.	Cost of Mains.	Cost of Converters.	Total.
2	1000	1000	$3,511	$84	$3,000	$3,084
5	1000	1000	1,347	33	3,000	3,033
2	1500	1000	7,910	197	3,000	3,197
5	1500	1000	3,156	78	3,000	3,078
2	2000	1000	13,952	330	3,000	3,330
5	2000	1000	5,675	141	3,000	3,141
2	4000	1000	56,282	1,407	3,000	4,407
5	4000	1000	22,512	562	3,000	3,562

From this table we see that, at the present cost of converters, the two systems cost the same, with two per cent loss at 1000 feet distance, with five per cent loss at a distance of 2500 feet distribu-

tion; and at five per cent loss the three-wire system is the most economical for shorter distances, while the induction system costs less for greater distances.

Our converters, when supplied with a constant electrical pressure of 1000 volts, return an approximately constant E. M. F. of 50 volts on the secondary circuit for all values of current between zero and full load.

I have constructed coils in which the loss of potential from all causes was less than one per cent, but in the commercial coil, limited by economical consideration, the loss is from two per cent to two and one half or three per cent; so that if the E. M. F. at the secondary is 50 volts on open circuit, it is 49 or 48.5 volts at full load. This self regulation is attained by first making the resistance of the coils as little as possible, and second by encasing them in an iron core of very low magnetic resistance.

When no current is abstracted from the secondary circuit of the coil the current in the primary circuit is very small,—so small as to be neglectible. The reason for this is that there is developed within the coil a counter E. M. F. almost equal to the E. M. F. applied, and the current flowing in the primary is urged by the difference of these E. M. Fs.

As current is abstracted from the secondary circuit it magnetizes the core of the coil in opposition to the magnetism developed in the primary, and this conflicting magnetism has the effect of increasing the magnetic resistance of the core just as the attempt to force two streams of water through the same pipe would conflict or oppose. Now, the counter E. M. F. in an induction coil is proportional, among other things, to the magnetic conductivity of the core,—from which it results that the counter E. M. F. is decreased by the current in the secondary circuit, and consequently more current flows through the primary circuit, because the difference between the applied and counter E. M. Fs., is greater; that is, the E. M. F. at work is greatest.

I have frequently been asked whether there is any difference (electrically speaking) between the ordinary Ruhmkoff coil and the modern potential transformer. I think there is. Both the old and the modern apparatus have the ability to transfer E. M. F. from one circuit to another, but they differ in this respect: In the old instru-

ment the potential was not equally distributed throughout the length of the coils. For instance: the inner turns on the Ruhmkoff coil, whether primary or secondary, have a greater difference of potential per turn developed on them than have the outer coils, more distant from the core; while in the modern converter, if the difference of potential, either impressed or developed, be of a given value for one turn of wire, the same value is developed or impressed on every other turn. Consequently, the fundamental law of the converter is the E. M. F. on any portion of wire in a converter is proportional to the number of turns.

There is no such law applicable to the older type of instrument. This new result in the induction coil is obtained in the simplest manner. It is evident that with a given rate of changes of magnetic field the E. M. F. developed in a conductor is measurable by the number of lines of force encircling it. Now, if we can arrange our conductor so that every line of force surrounding one portion of it surrounds all other portions, the E. M. F. developed on equal lengths of the conductor will be the same. In the older forms of coils this did not occur because of magnetic leakage.

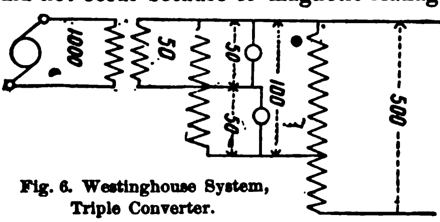


Fig. 6. Westinghouse System, Triple Converter.

One of the chief advantages attending the use of the induction coil for purposes of distribution is the facility with which any E. M. F. may be produced on the spot; that is, without changing the generating plant, as shown in figure 6.

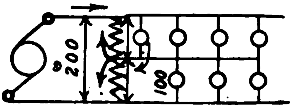


Fig. 7. Westinghouse Auto-Converter System.

In order to use the induction coil most economically for certain purposes, especially in case when the E. M. F. is not dangerous to life, I devised the method shown in Fig. 7.

You will notice in this case the E. M. F. applied to the coil is 200 volts; while the E. M. F. between the outside and intermediate terminals is 100 volts. Now, this single coil will regulate for and take care of many times the number of lights that the same sized coil would care for if wound with two insulated circuits, one primary and one secondary.

The waste of energy in this coil follows a very singular law.

The loss of energy is zero when the greatest number of lamps are in circuit,— that is, when an equal number of lamps are in each circuit. Comparing the maximum loss in this auto-converter with that in the standard induction coil under full load, at equal cost for coils, we have, for standard coil, a waste of energy as follows: —

$$\text{STANDARD CONVERTER.}\left\{\begin{array}{l}\text{Resistance} = \text{y ohms}\\ \text{Current} = \text{C amperes}\end{array}\right. \therefore C^2y = \text{Watts lost.}$$

$$\text{AUTO-CONVERTER.}\left\{\begin{array}{l}\text{Resistance} = \frac{y}{2}\text{ohms}\\ C = \frac{C}{8}\text{ amperes}\end{array}\right\} \frac{C^2}{64} \times \frac{y}{2} = \frac{C^2y}{128}\text{ Watts lost.}$$

So that the loss of the one is to the loss of the other as 128 is to 1.

The distribution of electrical energy by means of the high potentials and induction coils has almost annihilated the cost for the mains, while it has introduced the item of cost of converters. At present prices for converters and copper at twenty cents per pound, fifteen pounds of copper equal the cost of one lamp capacity in converters, and the purchaser has an equal option of using either the three-wire or converter system when distributing current at a distance of 1100 feet with two per cent loss; 1500 feet with five per cent loss, etc.

The paper was practically illustrated by several banks of lights in running order, showing the effects of the converters, etc.

Some discussion followed the paper, after which a vote of thanks to the speaker for his valuable paper brought the meeting to a close.

MEETING 369.

A Biological Examination of the Water Supply of Newton, Mass.

BY PROF. W. T. SEDGWICK AND MR. S. R. BARTLETT.

A New Method for the Biological Examination of Air.

BY PROF. W. T. SEDGWICK AND MR. G. R. TUCKER.

The 369th meeting of the SOCIETY OF ARTS was held at the Institute on Wednesday, Jan. 11th, at 8 P. M., Mr. E. S. Philbrick in the chair.

After the reading of the records of the previous meeting, the chairman introduced Prof. W. T. Sedgwick, of the Institute, who read the two following papers: —

FIRST. — A BIOLOGICAL EXAMINATION OF THE WATER SUPPLY OF NEWTON, MASS.

Prof. SEDGWICK said: The city of Newton gets its water from a filter basin 1575 feet long, running alongside the Charles River in the town of Needham. The water in the filter basin is pumped by engines in a pumping station near by to a reservoir some four miles distant on Waban Hill, from which it flows by gravity to all parts of the city. In the spring of 1887 the authors made in the Biological Laboratory of the Institute of Technology a quantitative bacteriological examination of the water from the Charles River, the filter basin, the reservoir on Waban Hill, and the tap in the city of Newton, estimating carefully the number of bacteria and molds in equal samples of water taken from the different localities on the same successive days. At the same time Mrs. Richards and Mr. Bartlett carried on a chemical examination of similar samples in the Institute Laboratory of Sanitary Chemistry. In the course of the investigations 145 biological and 117 chemical analyses were made; and all the work was done between April 1st and May 15th.

The method employed in the biological examinations was the well-known gelatine plate-culture method of Koch. The usual accessory apparatus was employed, and need not be described. The principle underlying the method is this: By mixing a known volume of the water under examination with a much larger volume of so-called "sterilized nutrient gelatine," the germs in the water are first *separated* somewhat widely from each other in the melted gelatine; and afterward, when the gelatine has been poured out on a cool plate carefully leveled, are *kept* separate and isolated by the stiffened mass. They are thus held securely apart, but may still easily grow and multiply in the nutrient mass, enriched as it is by meat extract, peptone, etc. At first the gelatine appears perfectly clear and pure; but after a day or two, comparatively opaque whitish or yellowish dots or islands may be detected, due to the rapid, though localized, increase of the germs. Each of these dots, if caused by bacteria, is

called a "colony," and is taken to represent one "germ" in the original water, provided the gelatine used was properly sterilized, *i. e.*, freed from all living germs. Molds have an equally characteristic though different appearance, and thus both may be recognized after a time, and the total number of living "germs" in the original sample readily and accurately estimated.

The water brought in for examination was collected and transported with great care in small glass-stoppered bottles holding about 60 c. c. These were carefully cleaned and enclosed in tin canisters made to fit them rather tightly, and all were thoroughly sterilized at 160° C. in the hot-air sterilizer. The tin covering prevented any accumulation of dust around the stopper, and allowed, without injury, considerable knocking about in transportation. In getting the sample of water desired the bottle was taken from its case, rinsed in the water to be collected, held well under, and filled by lifting the stopper. It was then returned to its tin case, and thus conveyed to the laboratory, where the culture was made, usually within three hours from the time of collection.

Some of the more important results are indicated in the following tables: —

NUMBER OF BACTERIA PER CUBIC CENTIMETRE OF WATER.

1887.	Charles River.	Filter Basin.	Waban Hill Reservoir.	A Tap in Newton.
April 1.	315	15	. . . . . .	. . . . .
April 6.	267	80	Apr. 11, 18	8
April 18.	220	48	48	6
April 27.	175	40	20	0
May 1.	200	15	10	4
May 9.	150	64	18	Apr. 29, 12
Averages . .	221	43	23	6

BACTERIOLOGICAL COMPARISON OF THE TAP WATER OF NEWTON AND BOSTON (BACK BAY) DURING ONE WEEK.

Date.	Colonies per c. c., Newton.		Colonies per c. c., Boston.	
	A	B	A	B
May 6.	0	4	48	60
" 7.	6	12	30	44
" 8.	Sunday.	Sunday.	Sunday.	Sunday.
" 9.	8	14	40	52
" 10.	0	4	24	60
" 11.	2	4	28	32
" 12.	0	8	25	35
" 13.	12	15	55	65
Averages . .	6		43	

Average number of bacteria per c. c. found in the water from

Newton (tap)	6
Boston (tap on the Back Bay)	43
Mystic (tap in Charlestown)	204
Spot Pond (pond)	38
Spot Pond (tap in Malden)	10
Jamaica Plain (Boston High Service)	52

The first table shows a considerable and constant difference in the abundance of living bacteria in the several waters examined, and indicates a progressive purity in this respect as the water nears the point of consumption. The largest difference between successive samples is that between the river water and that in the filter basin, and this is easily explained by a consideration of the conditions prevailing in each. The river is an ordinary stream, draining a rather thickly inhabited country, and hence is more or less polluted. The filter basin on the contrary, although dug parallel to the river and near it, probably gets from it little or no water. This comes instead from the other direction, owing to the slope of the adjacent country; and especially from eight artesian wells driven in its bottom to a depth of thirty feet, where they penetrate a quicksand and a gravel overlying bed-rock inclined toward the river. Thus it comes about

that the water in the filter basin is sometimes higher than that in the river, and always far more constant in temperature; and thus, too, it happens that the water of the river contained 221 germs per cubic centimetre in April and May, 1887, while that in the filter basin showed only 43. The filter basin, even to the naked eye, was much cleaner and purer than the river, although it contained a very considerable amount of filamentous algæ,—principally Zygnema. It is less easy to explain the progressive decrease of bacteria from the filter basin to the tap, but it is not unreasonable to suppose that the stock of organic matter, *i. e.*, of food for the germs, in this (principally) ground water was originally small, and gradually fell short.

The Newton water supply is generally regarded as very superior, and, as will be seen by inspection of the above tables, the biological examination abundantly confirms this view.

While the biological analyses just described were going on, a considerable number of chemical analyses of the Newton water was carried out in the Institute Laboratory of Sanitary Chemistry.

These chemical analyses of the water were likewise all made between the first of April and the middle of May, 1887,—a season which presumably would give as widely varying results as any season of the year.

From the accompanying table it will be seen that the amount of free ammonia was found to be more variable than that of the albuminoid ammonia. It seems to be also definitely established that the analysis of one sample of water, taken on a certain day at a certain season of the year, ordinarily gives no correct indication of the condition of the water the year round, since certain local causes may, for a few days, exercise a marked influence.

It will further be seen that the water was chemically (as well as bacteriologically) better when drawn from the tap than when taken from the reservoir or the filter basin. This may perhaps be accounted for by assuming that some of the organic matter settles out, and some is decomposed by the bacteria in the reservoir and the pipes.

CHEMICAL ANALYSES OF THE NEWTON WATER SUPPLY.

PARTS PER 100,000.

	Charles River.		Filter Basin.		Reservoir.		Tap.	
	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.	Free Ammonia.	Albuminoid Ammonia.
Apr. 1	.0070	.0250	.0150*	.0078				
" 6	.0030	.0212	.0014	.0088				
" 11					.0018	.0100		
" 18	.0046	.0254	.0038	.0118	.0320†	.0158	.0018	.0056
" 27	.0012	.0264	.0018	.0138	.0038	.0096	.0004	.0080
May 1	.0014	.0264	.0026	.0126	.0030	.0130	.0004	.0050
" 9	.0050	.0194	.0004	.0120	.0016	.0094	.0012	.0063

On April 1st the ice had just begun to break up.

* Possibly due to melted ice, or to the fact that the water under the ice is more nearly stagnant.

† Taken just after a snow storm. The banks of the reservoir had also been recently dressed with fertilizer.

SECOND.—A NEW METHOD FOR THE BIOLOGICAL EXAMINATION OF AIR.

The authors were led to devise a new method for the biological study of the air in order to overcome, if possible, the obvious defects of the methods hitherto in use. The principal methods so far employed are:—

1. *Hesse's*, in which a known volume of air is drawn through a long tube coated inside with sterilized nutrient gelatine, upon which the germs may fall and grow and afterwards be counted. The chief defect here is that some germs pass through and are lost, only the heaviest being detained.

2. *Frankland's*, in which the air is drawn through sterilized glass wool, powdered glass or some other substance, and is thus filtered; after which the filter or plug containing the germs is transferred to a flask of melted sterilized nutrient gelatine, shaken thoroughly, and the whole cooled down. The germs are thus fixed, but mixed with the gelatine, and may be counted in the usual way. Several defects exist in this method,—notably the possibility of loss

or infection during the transfer, the difficulty of mixing the plug with the gelatine without getting in air bubbles, and the chance of difficulty in counting the colonies owing to the presence of the filtering substance. *Petri* (who claims that Frankland's is but a modification of a method devised earlier by himself) employs sand for the filtering medium, with the obvious advantage of ready and thorough sterilization, but with the similar disadvantage of an insoluble residue to be avoided in counting. Petri, moreover, transfers his filter as does Frankland.

The authors began with Frankland's method, and undertook to improve it. A soluble filter was sought for, first in spun sugar and finally in granulated. Transfers were made at first as in the method of Frankland and of Petri; but a special form of tube was soon devised, which avoids this necessity. The tube, therefore, quite apart from the filter, constitutes an important advance, since the gelatine is now carefully added to the filter (and contained germs) instead of *vice versa*. The advantage of this is great, for not only are fewer dishes, etc., needed, but what is of more importance, the danger of undue loss or gain of germs during transfer is wholly overcome. Again, the gain from the use of a soluble filtering medium is self-evident, since the germs are left absolutely embedded in gelatine, and may be counted as easily as in a Hesse tube. The apparatus, indeed, may be described as a short and portable Hesse tube, narrowed unequally at the ends, one of which is stopped during the experiment with granulated sugar carefully sterilized. By means of an exhausted receiver, fitted with a vacuum gauge, a known volume of air is readily drawn through the tube, and leaves its germs (as has been proved by experiment) in the filter of sugar. With proper precautions, sterilized gelatine is introduced at the free end, the tube stoppered, the sugar dislodged and shaken into the gelatine, dissolved, and the germ-laden gelatine then spread as a coat over the inside of the tube. After incubating the germs in the usual way they are readily counted by the aid of squares etched or ground upon the outside of the tubes.

The complete apparatus for the above examinations was exhibited, as were also several of the culture tubes containing living bacteria, and molds in different stages of development.

MEETING 370.

Steam Engine Experiments in the Mechanical Engineering Laboratory of the Mass. Institute of Technology.

BY MR. A. J. PURINTON.

A General Review of Steam Engine Tests.

BY PROF. C. H. PEABODY.

The 370th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Jan. 26th, at 8 P. M., Hon. J. A. Dresser in the chair.

After the reading of the records of the previous meeting and the election of new members, the chairman introduced Mr. A. J. Purinton, who read a paper on "Steam Engine Experiments in the Mechanical Engineering Laboratory of the Mass. Institute of Technology."

Mr. PURINTON said: In making a test on any engine, the principal things we want to find are the amount of work done by the engine and the amount of steam which it takes to do that work, and these two things taken together will tell us if the engine is working economically.

To find the work the engine is doing we usually make use of the steam-engine indicator, which gives, by means of its peculiar construction and connection with the cylinder and cross-head of the engine, a closed curve, and from the enclosed area we can find the work done, as will be spoken of later.

The amount of steam used can be accurately determined by condensing the exhaust steam and weighing it, or, by weighing the feed water before it enters the boiler. In this case the steam from the boiler should be used only for the engine. The former way is preferable to the latter, but of course requires the use of a condenser, which is not always available. The method of making and working up our tests is as follows:—

The exhaust steam from the two engines in the M. E. Laboratory passes into a surface condenser under atmospheric pressure, and thence into a tank on platform scales where it is weighed.

The amount of steam used by the engine at the shops is ascertained by weighing the feed water of the boiler, as during the tests it is used only by the engine.

A gong is struck at five-minute intervals, when indicator cards are taken, one from each end of the cylinder, also the weight of the tank and contained water, the boiler pressure, reading of counter, and time of gong. In this way the amount of water accumulated in the tank during each five minutes is ascertained, and the number of revolutions of the engine during the same time. These results are recorded upon a blank log furnished for the purpose.

The next thing is to work up the cards. From the indicator diagram we can learn several things. It tells us at what part of the stroke steam is admitted to the cylinder, when the admission valve closes at cut-off, when the exhaust valve opens at release, and when it closes at compression. From it we can calculate, with the aid of other data, the horse-power, the weight of steam in the cylinder of the engine at cut-off, at release, and at compression. The weight of the steam used can also be calculated from the diagram, but this calculated value is smaller than that obtained by the tank, the difference being due to a certain amount of water in the cylinder which is not accounted for by the indicator, as in calculating this amount from the card we assume the steam to be saturated, and that no water is present.

The experiments show also a greater weight of steam in the cylinder at release than at cut-off, which must be due, provided the valves are tight, to the evaporation of an amount of water during expansion as the pressure decreases. Thus, to take the simplest case for illustration, if there is no back pressure, and the engine is single acting, *i. e.*, takes steam only on one side of the piston, during the return stroke the steam in the cylinder, being under atmospheric pressure, has a temperature of 212° F.

The temperature of the cylinder then will be somewhere near that of the steam.

Now, if steam at 70 pounds pressure above the atmosphere be admitted, having a temperature of about 318° F. due to that pressure,

the cylinder will be heated to approximately that temperature. To do this, a certain amount of steam must be condensed, which accounts for the water present at cut-off.

Between cut-off and release, as the piston travels onward, the volume which the steam occupies is increased, thus reducing its pressure, and consequently its temperature. Then, as the temperature of the cylinder is higher than that of the steam and water in it, some of the latter is evaporated, giving a greater weight of steam at release than was in the cylinder at cut-off, although the weight of the mixture of steam and water is the same at both points in the stroke.

The indicator diagram shows also the pressure per square inch in the cylinder for every part of the stroke.

To get the mean effective pressure, that is, the average pressure per square inch on the piston for the whole stroke, the area of the card is divided by the length, the quotient being the mean hight. This hight is then multiplied by the number of the spring, and the result is the mean effective pressure.

The mean back pressure, if any, may be found in the same way. These results, together with the per cent of the stroke at which cut-off, release, and compression take place, are found for each card, and the average taken for the cards of each end, which gives two average cards, one for each end, from which the final results are calculated.

The piston displacement, that is, the area of the piston, multiplied by the length of the stroke, both expressed in feet, the clearance, given in terms of the piston displacement, and constant (horse-power for one pound mean effective pressure and one revolution per minute) have been determined beforehand for each end of the cylinder, and do not vary for any one engine.

The horse-power for each end of the cylinder is obtained by multiplying the constant by the mean effective pressure for that end, and this product by the number of revolutions per minute. The total horse-power is found by adding the horse-power for the two ends together.

To find the weight of steam at cut-off, its volume must first be found. The per cent of the stroke at which cut-off takes place is added to the per cent of clearance, and the sum multiplied by the piston displacement gives the volume of the steam which expands as the piston moves onward.

Recorded upon the log is the pressure above the atmosphere of the steam; and to this the atmospheric pressure, found from the barometer, is added, giving the absolute pressure above a vacuum of the steam at cut-off. Multiply this volume by the weight of a cubic foot of saturated steam, corresponding to this absolute pressure, and the product will be the weight of steam in the cylinder per stroke at cut-off. The weight per revolution is found by adding the weight per stroke for the two ends of the cylinder.

The weight at release, and at compression, is found in the same way.

The weight of water per revolution, shown by the tank, is obtained by dividing the total weight of water by the whole number of revolutions during the test.

The weight shown by the indicator is found by subtracting from the weight of steam per revolution at release the weight at compression per revolution.

To find the weight of water per hour, the weight per revolution is multiplied by the number of revolutions per hour. The quotient, obtained by dividing this last by the total horse-power, will give the water per horse-power per hour.

Adding to the weight of water per revolution by the tank the weight of steam at compression per revolution shown by the indicator will give the weight of the mixture of steam and water in the cylinder per revolution.

In making these calculations, it is assumed that there is no water present in the cylinder at release, and that the steam is saturated. There is, however, some water present, as in all the experiments the weight of water given by the tank is greater than that shown by the indicator. It is assumed also that the steam at compression is saturated, and that there is no water present at that point, — which seems to be a fair assumption, as the steam in the exhaust pipe has shown when tested only about four per cent priming.

To get the pounds reëvaporation in the cylinder per hour, subtract the weight of steam at cut-off from the weight at release per stroke for each end of the cylinder, add the two, and multiply the sum by the revolutions per hour. Divide this by the total horse-power, and the quotient will be the pounds reëvaporation per horse-power per hour.

From the results of the tests on the Porter-Allen and Harris-Corliss engines, a number of curves have been plotted, and were shown on the screen, from some of which it was seen that the amount of water consumed decreased quite rapidly at first as the horse-power increased, and afterwards much more slowly, which shows the disadvantage of running an engine with a very light load. When running the Porter-Allen at 20 horse-power, the water per horse-power per hour was 70 pounds, and when running at 45 horse-power it was less than 40 pounds. In the same way with the Harris-Corliss, at about 5 horse-power the amount of water used was between 55 and 60 pounds, while at 12 horse-power it fell to 38 pounds. The largest and smallest amounts of water per horse-power per hour, shown by the Porter-Allen tests, were 70.7 and 37.4 pounds, with 20 and 40 horse-power respectively. For the Harris-Corliss the largest was 58 pouuds with 5 horse-power, and the smallest 35 pounds with 11 horse-power.

Other curves showed that the per cent of the mixture shown as steam increased as the length of the cut-off increased, and that the per cent shown at cut-off increased much more rapidly than at release.

Still other curves showed that at first the amount of water decreased quite rapidly as the cut-off was lengthened, and afterward more slowly, up to 35 per cent, which was the maximum obtained in these experiments. These also showed that the effect of lengthening the cut-off was the same on both engines, although one runs at 200 revolutions per minute, while the other runs at only 60 per minute.

Other curves showed that for a short cut-off the reëvaporation was very great, and that it decreased very rapidly as the cut-off was lengthened; the Harris-Corliss giving a reëvaporation per horse-power per hour of 31 pounds for a cut-off of 9 per cent, and only about 4 pounds for a cut-off of 30 per cent; the shortest cut-off of the Porter-Allen engine, 16 per cent, showed 19 pounds, and the longest, 36 per cent, a little less than four pounds.

A GENERAL REVIEW OF STEAM ENGINE TESTS.

At the close of Mr. Purinton's paper, the chairman introduced Prof. C. H. Peabody, of the Institute, who read a paper on "A General Review of Steam Engine Tests."

Prof. PEABODY said: In no branch of engineering has the divergence between theory and practice been wider than in steam engineering. The theorist, working with legitimate mathematical methods, but with insufficient data, arrived at conclusions that were in error to the extent of a quarter or a third of the quantities under consideration. On the other hand, the practical man was aware of the discrepancy beween the actual and the calculated result, and, being none too familiar with the rather abstruse methods of thermodynamics, concluded either that the theoretical work was altogether useless, or else that "it might be true in theory, but it was not so in practice."

The difference appeared most markedly between the form of the expansion curve drawn by the indicator and the form assigned to that curve by theoretical deductions from experimental work of undoubted accuracy. It appeared rather unfortunate that the later and more refined theories gave the greater divergence. In the time of Watt the expansion of saturated steam was assumed to follow the same laws as gases at a constant temperature. The resulting expansion curve was a rectangular hyperbola, with which the actual curve on the indicator card agreed fairly well. Later investigations showed that the curve obtained by laying off the corresponding pressures and volumes of dry saturated steam was steeper than the hyperbola. Again, the application of correct mathematical methods to the best experimental data showed that the expansion in a non-conducting receptacle of steam, originally dry and saturated, was accompanied by a condensation of a portion of the steam, and consequently the curve representing such an expansion was steeper than the curve of saturated steam, which in turn was steeper than the hyperbola.

Again, all the theories from the time of Watt showed that the earlier the cut-off and the greater the expansion of steam in a steam engine the greater the efficiency; but the coal bill alone showed that a limit to gain by increased expansion was soon reached, and that excessive expansion was accompanied by great loss.

It is but fair to say that the theories proposed were all confessedly incomplete, in that none of them took account of the action of the walls of the cylinder of the engine on the steam contained. It was tacitly assumed that the action must be small, since the time of a single stroke of an engine even at moderate speed of revolution was short. Moreover, no experimental data on the subject existed,

which made it more convenient to make the omission than to try to make some allowance for such an action. Even today we cannot be said to have any further information than that the action of the walls is energetic, and that it takes place in a fraction of a second.

The only proper solution of such a difficulty is by means of experiment, but an investigation shows a surprising paucity of material. Even what does exist is more qualitative than quantitative.

Tests may be divided into two classes: those for commercial and those for theoretical purposes. The first determine the cost in money or in coal of doing certain work. The second require that enough data should be obtained to completely solve the problem of the behavior of steam in the engine.

Of the first class we have a large number. Any reputable maker of pumping engines will guarantee a certain duty, and large engines of all classes are frequently contracted for on the basis of a certain coal consumption. In either case a test is made to prove the performance. In attempting to use the results of such work for theoretical purposes, we are at once confronted by the lack of sufficient data, even when the work is done with a care and accuracy that would otherwise be quite sufficient. Formerly no attempt was made to separate the action of the boiler and the engine; but now it is customary to make such a separation, even when the coal consumption is the ultimate object sought, by determining the consumption of steam by the engine in pounds per horse-power per hour. When enough other data are given this gives the basis for the calculation of the consumption of heat, measured in heat units, which is the logical measure of the efficiency of any form of heat engine.

The steam consumption may be determined by weighing or measuring the quantity of feed water supplied, when steam is supplied to the engine undergoing test alone. In such work the use of a water meter is to be deprecated, and the data of a test when a meter is used are of value only when that individual meter is subjected to careful and extensive tests to determine its errors.

Should the engine have a surface condenser the condensed steam may be measured instead of the feed water, and a test may be of less duration, since the flow of water from the condenser is more regular than the supply of feed water, and because the total quantity of water in the condenser is so small that a considerable variation

in that quantity has a less influence than a proportionate variation of the quantity of water in the boiler.

Further, we ought to know the condition of the steam furnished to the engine,— that is, whether it is superheated or moist. In the first case a moderate degree of superheating at ordinary pressure may be determined by placing a thermometer in the steam pipe near the engine. In the second case, the per cent of moisture can be determined only by a calorimeter test, which commonly is not done on account of the unsatisfactory results given by the ordinary methods of experimenting that are good enough for determining the other quantities, but not refined enough for this purpose.

The importance of this is emphasized by the fact that Zeuner, in his *Wärme theorie* (1877), assumes that the steam furnished to the cylinder of a locomotive has 25 to 30 per cent of priming, simply because such an assumption allows him to determine a theoretical curve, neglecting the action of the walls of the cylinder, which agrees well with the curve of the indicator diagram from such engines. The usual assumption that the steam is dry may be in error 5 or 10 per cent, but is very commonly a fair one.

I shall now give a brief review of some of the more notable experiments, and show the conclusions to be drawn from them.

Chief Engineer Isherwood, a number of years ago, made some extensive experiments on an engine having a diameter of $5\frac{1}{2}$ inches, and a stroke of 10 inches, and developing about one horse-power, with a boiler pressure of 10 to 50 pounds of steam. The engine was supplied with a steam jacket, and had a jet condenser. The steam for the engine was sometimes drawn directly from the boiler, and was moist or primed to a small but unknown degree. In other experiments the steam was superheated by a peculiar method to a moderate degree. The steam pressure was 50 pounds, and cut-off was at 19 per cent of the stroke. Without going into details, we may select the conclusions shown in Table I as having some interest even at the present day.

The notable facts drawn from the experiments are the large consumption of steam per horse-power per hour, especially when saturated steam was used and the jacket was not on, and the large per cent of this consumption that is not shown by the indicator. These tests show in a marked manner that the walls of the cylinder

TABLE I.

TEST ON SMALL ENGINE, $5\frac{1}{2}'' \times 10''$.	Saturated Steam Jacket off.	Saturated Steam Jacket on.	Superheated Steam Jacket on.
Steam per indicated H. P. per hour.	79.5	51.9	42.4
Per cent not shown by indicator.	65.7	54.3	44.9
Gain by jacketing or superheating.	48 per ct.	19 per ct.	

have an important effect on the action of the steam contained, and the conclusion is inevitable that the poor economy is due to the excessive condensation of steam in the cylinder. Such condensation is more noticeable in small engines than in large, since the area varies as the square, while the volume varies as the cube of the diameter, and the condensation must in some manner vary with the surface.

Recognizing this fact, Mr. Isherwood made a test on a large pumping engine, having a diameter of 90 inches and a stroke of 10 feet, and developing about 430 horse power, with 12 pounds pressure in the boiler. The engine made 42 strokes a minute, and had a cut-off at 62 per cent of the stroke. The engine was jacketed with steam on the sides but not on the ends. It was found that the consumption of steam per horse-power per hour was 36.4 pounds when the steam jacket was not used, and 35.4 when it was in use. The per cent of steam not shown by the indicator in the first case was 14.30 per cent, and in the second case, including that condensed in the jacket, was 11.98 per cent.

These two tests are to be considered as extreme cases, and the true gain in practice from the use of a steam jacket is intermediate between that shown by them.

In 1861 experiments were made by a board of U. S. naval engineers on the engine of the U. S. paddle-wheel steamer *Michigan*, to determine the most economical point of cut-off under conditions of the use of steam in engines of its class. The diameter of the cylinder was 36 inches, and the stroke was 8 feet. It made from 11 to 20 revolutions during the test, and developed from 60 to 340 horse-

power. The cylinder was lagged on the sides but not on the ends, and had no steam jacket. Steam at 40 pounds boiler pressure was used. The following table gives the conclusions from the test: —

TABLE II.

TESTS ON THE MICHIGAN.

Cut-off.	Horse Power.	Steam per Horse Power per Hour.	Water at end of the Stroke.
11-12	301.4	39.9	10.7
7-10	210.8	34.8	15.3
4-9	204.4	33.1	27.2
3-10	133.7	35.2	42.6
1-4	118.4	34.5	39.7
1-6	74.5	37.0	42.1
4-45	60.9	46.1	45.1

The best point of cut-off was at $\frac{4}{9}$ of the stroke; but the consumption of steam is nearly the same for a cut-off varying from $\frac{1}{4}$ to $\frac{7}{10}$ of the stroke. The advantage of small size and simplicity of valve gear makes it certain that an engine having a cut-off at $\frac{7}{10}$ of the stroke would be most satisfactory under the conditions given.

Again, in 1864, a series of tests were made by a board of U. S. naval engineers on the engine of the U. S. steamer *Eutaw*, to determine the effect of using superheated steam. The diameter of the engine was 4 feet 10 inches, and the stroke was 8 feet 9 inches, and was lagged but not jacketed. The engine used steam of about 40 pounds pressure, which was taken directly to the engine in some of the tests, and in others it passed through a superheater on the way thither. The results of the tests are given in Table III.

TABLE III.

TESTS ON THE EUTAW.

	Saturated Steam.				Superheated Steam.			
Cut-off.	24	32	50	58	29	32	50	58
Steam per H. P. per hour.	39.2	31.0	33.2	32.0	30.5	28.3	26.3	27.8
Water in the cylinder at the end of the stroke	56%	37%	30%	24%	43%	38%	18%	18%

The use of steam superheated about 96° F. above the temperature in the boiler at one-half stroke cut-off was accompanied by a gain of about 20 per cent. When the cut-off was at 58 per cent of the stroke, superheating 123° F. gave a gain of about 15 per cent.

The table shows a steady decrease of the quantity of water in the cylinder at the end of the stroke as the cut-off is increased for each series of experiments. The effect of the superheating is clearly to reduce the quantity of water in the cylinder at the end of the stroke, and it is readily inferred that this is the reason for the greater economy with the use of superheated steam.

Now, the water at the end of the stroke has thus well served to call our attention to the action of the walls of the cylinder on the behavior of the contained steam; but, as was shown by the tests in the laboratory of the Institute, it tells but a part of the story, for, during the expansion of the steam after cut-off, much of the steam previously condensed is reëvaporated. It may be worth while to stop and consider what is the true action of the walls of the cylinder on the steam.

At the beginning of the stroke the steam from the boiler comes into the clearance space at the end of the cylinder and the steam passages, a space which from its form has a large surface for its volume, and is condensed upon the surface with exceeding rapidity. During the stroke new cool surfaces are uncovered by the piston, and the condensation goes on up to the point of cut-off, or a little beyond. After cut-off the pressure is reduced by expansion till it is less than that corresponding to the boiling point of the water condensed on the walls of the cylinder and adhering to them. That water is consequently evaporated in part at the expense of the heat acquired by the walls during its condensation. At the end of the stroke the pressure suddenly drops to that of the condenser or the atmosphere, and nearly if not quite all of the remaining condensed water in the cylinder is vaporized, and takes from the walls of the cylinder the remainder of the heat acquired during admission of steam to the cylinder. The action of the walls during the compression we may neglect for the present, for it is small when the compression is small, as in the Corliss engines.

Of the heat acquired by the walls of the cylinder during admission, a part is restored during the expansion, on account of the

reëvaporation of part of the water condensed on them. This is accompanied by a loss of efficiency, as may readily be shown in the discussion of thermodynamics, but the heat is not all lost. On the other hand, the heat yielded by the walls during exhaust is absolutely thrown away; hence the amount of water in the cylinder at the end of the stroke, and evaporated during the exhaust is in some way a measure of the efficiency of the process of any steam engine.

This exhaust waste is not to be confounded with the heat rejected in the steam, which exists as steam at the end of the stroke. Every heat engine doing a large amount of work *must* take in a large amount of heat at a high temperature, and *must* reject the larger part of this at a lower temperature; the difference having been changed into work. The great latent heat of steam which at first appears to be a serious disadvantage, since we must use much fuel to turn the water into steam in the boiler, and then use much cooling water in the condenser to turn the steam back into water, is in reality that property which enables us to make compact serviceable engines. In designing engines to use hot air, the difficulty is to make the working substance, which being a gas has no latent heat due to change of condition, take in and give out heat in sufficiently large quantities to make a powerful engine of compact size. Of course, in such a comparison we should compare engine, boiler, and furnace for one with furnace and engine for the other.

Hirn has shown that we may not only recognize the action of the walls of the cylinder on the steam, but that we may determine experimentally the quantities of heat taken in by the walls during admission, and restored during expansion and exhaust. Of a considerable number of experiments made by himself and his followers in France, we will now consider a few which bring out clearly the manner in which superheated steam, or a steam jacket, each reduces the exhaust waste, for the action is quite distinct in the two cases.

We shall not stop to consider the method of making the calculation further than to say that the proper equations are deduced on strict thermodynamic principles, and have been most clearly stated by Zeuner, who contested the conclusion from Hirn's experiments.

During the years 1873, 1875, and 1878 a number of experiments were made by Hallaner and associated members of the Société Industriélle de Mulhouse on two simple expansive engines: one of a

form designed by Hirn to use superheated steam, and the other of the Corliss type, which was provided with a steam jacket, and used saturated steam.

The data of the experiments are very complete, though unfortunately only a part of them appear to be accessible since the death of Hallauer; in all other cases the results only are at hand.

Three of the experiments, which appear to be comparable and which bring out the points for which we are looking, are given in —

TABLE IV.

EXPERIMENTS ON HIRN AND CORLISS ENGINES.

	Horse Power Cheval-à-Vapeur.	Steam per H. P. per hour. Kilograms.	Cut-off.
(1) Hirn-Superheated.	144	7.6	1-4
(2) Hirn-Saturated.	136	9.3	1-4
(3) Corliss-Jacketed.	158	7.8	1-6

Per cent of Water in Cylinder.		Exchange of heat in per cent of total heat furnished per stroke.		
Cut-off.	Release.	Absorbed during admission.	Restored during expansion.	Wasted during exhaust.
6.5	12.0	11.0	2.0	7.8
30.4	25.2	23.9	7.3	15.4
25.3	18.5	15.4	10.4	8.0

The Hirn engine using superheated steam has a slight advantage in consumption over the Corliss engine. The Hirn engine using saturated steam has a much greater consumption than either of the two other experiments. No experiments were made on the Corliss engine without its jacket, but it would probably give a like result under such condition.

The quantity of water in the cylinder at the end of the stroke, and the heat wasted during exhaust, give a ready explanation of this diminished efficiency, the latter quantity being nearly the same for each engine in its economical working condition.

Here the parallel ceases. The use of superheated steam reduces the condensation during admission, and consequently the heat given to the walls during that period; but of that heat only a trifling amount is restored during expansion. The use of the steam jacket is most efficacious in reëvaporating the condensed water during expansion, so that the exhaust waste is reduced by the restoration of heat before release. An examination of the methods of action will explain the difference of the results. When superheating is carried to a sufficient degree the heat required by the walls of the passages and the clearance space is furnished by the superheat aided by a small condensation. During expansion the condensation on the cool surfaces exposed by the piston is about equal to the evaporation due to reduction of pressure. There being but little water to evaporate during exhaust the waste from that cause is small, and much less heat is required to replace it during the admission. The steam jacket evaporates during exhaust the water condensed at the beginning of the stroke, and thereby reduces the exhaust waste, and consequently the initial condensation is less than when no jacket is used.

In connection with these experiments we may quote some made by Mr. Dixwell on the use of superheated steam in the Harris-Corliss engine in the laboratory of the Institute, of which the results are given in Table V.

TABLE V.

EXPERIMENTS ON THE HARRIS-CORLISS ENGINE.

	Kind of Steam.	Cut-off.	Temperatures.		Horse-Power.
			Steampipe.	Cylinder.	
1.	Saturated.	0.22		263-267	7.6
2.	"	0.44		264-268	12.7
3.	"	0.69		268-273	15.7
4.	Superheated.	0.22	478	300	6.8
5.	"	0.44	441	306	12.4
6.	"	0.67	406	305	15.6

Continuation of Table V.

	Per cent of Water in Cylinder.		Steam per H. P. per Hour.
	Cut-off.	Release.	
1.	52.2	32.4	48.2
2.	35.9	29.3	42.2
3.	27.9	23.9	45.3
4.	27.9	18.3	35.2
5.	13.6	13.6	31.7
6.	8.9	11.5	35.8

In addition to the large gain by the use of superheated steam at 50 pounds pressure used during the experiments, the notable fact appears that a large degree of superheating in the steampipe is accompanied by a very moderate increase of temperature in the cylinder. At the most economical point of cut-off, namely, 44 per cent of the stroke, the balancing of evaporation and condensation during expansion is quite perfect.

In 1870 the U. S. Coast Survey steamer *Bache* was built with a tandem compound engine, having a steam jacket on the large cylinder but none on the small cylinder, as it was inconvenient to arrange for one on that cylinder in its position over the large cylinder. The cylinders had diameters of 16 and 25 inches and 25 inches stroke. An arrangement was made by which steam could be carried directly from the boiler to the large cylinder in case it appeared desirable to do so. The results of tests on this engine in its normal condition, working compound with steam in the jacket, are given in Table VI.

TABLE VI.

EXPERIMENTS ON THE BACHE,
PRESSURE 80 POUNDS, REVOLUTIONS 50.

Total number of Expansions.	Steam per H. P. per Hour.	Accounted for by Indicator.		Condensed.	
		Small Cylinder.	Large Cylinder.	In Jacket.	In Receiver.
16.8	25.1	58	74	6.5	11.2
9.2	20.7	68	76	7.	10.
7.0	20.3	74	73	5.1	7.6
5.7	22.	72	73	5.4	6.9
4.2	21.	82	77	4.	5.0

During the experiments the steam condensed in the receiver between the small and large cylinders was drawn off and weighed separately; had it passed on into the large cylinder, much of it would have been evaporated in that cylinder. When steam passes in that way from one cylinder to the other, it is commonly drier in the large cylinder than in the small cylinder. In triple compound engines, in which the steam passes through three cylinders, it is much dryer in the large or low pressure cylinder if the condensation in the intermediate pipes and receivers is not excessive.

The results of experiments made on the engine with the steam led to the large cylinder directly, and with steam in the jacket, are given in Table VII.

TABLE VII.

EXPERIMENTS ON THE BACHE, SINGLE.

WITH JACKET.

Total Expansions.	Steam per H. P. per Hour.	Steam Shown by Indicator.
12.6	27.1	61
8.6	24.1	64
5.1	23.1	70
2.2	34.0	71

WITHOUT JACKET.

Total Expansions.	Steam per H. P. per Hour.	Steam Shown by Indicator.
11.8	35.1	60.0
7.6	29.6	55.5
5.3	26.2	66.1

A comparison of Tables VI and VII shows that the largest number of expansions for the single engine should be 5, but for the compound engine may be from 7 to 9. Under these most favorable conditions the water at the end of the expansion to be evaporated during exhaust will be for the simple engine 30 per cent, while for the compound engine, allowing for the condensation in the receiver and the jacket, it is only 14 per cent. The gain from the greater expansion, and the reduction in the exhaust waste, are sufficient to explain the saving of 12 per cent in the consumption of steam.

In 1874 three U. S. revenue steamers were built on the same lines and were essentially the same, except that they were supplied with three types of engines, each engine being designed to give the same horse-power with the best economy for its type, and furnished with proper boilers.

The *Rush* had a receiver compound engine with cylinders 24 and 38 inches in diameter and 27 inches stroke, both cylinders being lagged and jacketed. The steam pressure was 80 pounds.

The *Dexter* had a single cylinder engine 26 inches in diameter and 36 inches stroke, lagged but not jacketed, using steam of 70 pounds pressure.

The *Dallas* had a single cylinder engine, 36 inches in diameter by 30 inches stroke, lagged but not jacketed, and using steam of 40 pounds pressure.

Without going into the details of the experiments, we may note the conclusions drawn from the experiments on these engines, and those on the engine of the *Bache*.

The high pressure engine of the *Dexter* had an advantage in consumption of steam of 13 per cent over that of the low pressure engine of the *Dallas*.

The compound jacketed engine of the *Rush*, using 70 pounds pressure of steam, had an advantage of 23 per cent over the single unjacketed engine of the *Dexter* using the same pressure. If it be assumed that the addition of a steam jacket to the engine of the *Dexter* would have been as efficient as that of the jacket on the engine of the *Rush* was shown to be when running single, then the advantage of the compound over the single engine would have been 13 per cent.

Now, in practice it is claimed that compounding is accompanied by a gain of 20 per cent. Mr. Emery, in reviewing these experiments, thinks that this is due to the fact that a large expansion in a single cylinder gives an undesirable distribution of work throughout the stroke of a marine engine. The engineer of the boat finds that a more advantageous distribution, which adds to his own convenience, can be obtained by lengthening the cut-off, and either reducing the boiler pressure or by partially closing the throttle valve. The accompanying reduction of economy does not deter him from doing so. On the other hand, the cut-off in a compound engine is seldom incon-

veniently short; and, moreover, the engineer finds that he must keep up the pressure in the cylinder in order to maintain speed.

The experiments on the engines of these four vessels give the data for the determination of the advantage of the use of a steam jacket.

(1.) Experiments on the engine of the *Bache*, using the large cylinder only, with and without steam in the jacket, showed a gain of 12 per cent from its use.

(2.) Experiments on the same engine used compound, with a jacket on the large cylinder, and with steam excluded from that jacket, showed a gain of 12 per cent from the use of the jacket.

(3.) An indirect comparison showed that the gain from the use of jackets on both cylinders of the engine of the *Rush*, as compared with the engine of the *Bache*, having a jacket on the large cylinder only, was insignificant. Though the method of the comparison is unsatisfactory, it is yet evident that a jacket on the large cylinder is more essential than one on the small cylinder.

A number of French tests on compound stationary and compound engines are reported by Hallauer. As a whole they are very remarkable, but their practical value is lessened by the fact that many of the tests were made with too low a pressure to make compounding advisible. One thing however may be stated without quoting the figures for the proof. He found that there was a considerable condensation and transfer of heat to the walls of the small or high pressure cylinder. Of this heat a part only was restored during the expansion in the small cylinder. He found that there was a large transfer of heat from the walls of the small cylinder to the walls of the large cylinder, but that during the double expansion from the small cylinder to the large cylinder, and after cut-off in the large cylinder, the heat was almost entirely restored from the walls of the large cylinder, so that in engines of good design, and working under favorable conditions, the exhaust waste was small.

In conclusion, it is to be desired that experiments may be made on the modern high pressure compound engines of large size. Since the engines are mostly marine engines, it is difficult to measure the water consumption during the ordinary trial trips, and the coal consumption is but too often determined from too short runs, and by a method of estimating the fuel on the grates that cannot be com-

mended. To show the limit of steam engine performance, which may be approached but cannot be equaled, I will refer to Table VIII, which is calculated from Regnault's experiments by the accepted methods of thermodynamics, and which cannot be in error to the amount of one per cent, and which is probably correct to one-third of one per cent.

TABLE VIII.

Pressure.	Pounds of Steam per H. P. per Hour.	
	Condensing.	Non-Condensing.
15	15.4	51.1
30	13.6	32.8
60	12.8	22.9
100	10.9	18.9
150	10.2	16.0
200	9.8	14.6

MEETING 371.

The Manufacture of Paper, and its Uses.

BY HON. WM. A. RUSSELL.

Natural Gas.

BY PROF. L. M. NORTON.

The 371st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Feb. 9th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting and the election of new members, the President introduced Hon. Wm. A. Russell, who read a paper on "The Manufacture of Paper, and its Uses."

Mr. RUSSELL first spoke of the primitive character of the articles that preceded the use of paper; first stone, wood and bricks, on which the sign or character writing was cut; then papyrus, made from the plant of that name by splitting it into its natural laminæ, and pressing them together, forming thin sheets upon which writing was done by the use of pen and ink, and finally parchment made from the skins of animals.

It was not until the tenth century that the process of making paper from fibrous substances, being first reduced to pulp and then united again, found its way into Europe from China.

In all kinds of paper making, whether from the bark of trees, or other fibrous matter, or from rags, the preparatory process is substantially the same,—the materials are cut into pieces from one to two inches in length, then bruised or drawn out in water into short uniform filaments called pulp. At first the pulp was pounded out in mortars by hand. This method was superseded in the fifteen century by crude machines, and in 1750 a machine, substantially the same as is now in use for making pulp, came into use.

The paper was first made into sheets by hand, and a much higher standard of skill was required than is needed today. No man could find employment as a journeyman unless he had served a seven years' apprenticeship. The mold in the hands of a skilled workman would turn out sheets of paper as uniform and nearly as fine in texture as are produced today by machinery. The use of paper increased rapidly in all countries after the invention of the press, but nowhere as it has in the United States.

The census returns for 1880 show that we had reached the enormous yearly consumption of 855,000,000 pounds of paper. The increase in population and increase in the consumption of paper for new uses would doubtless carry the amount nearly, if not quite, up to 1,000,000,000 pounds in the current year. This divided among our population would be about seventeen pounds per capita, while the consumption of paper in England does not exceed eleven pounds; in France nine pounds; in Germany eight pounds.

The lecturer next spoke of the great variety of articles which are made of paper, as water pipes, boats, boxes, billiard balls, belting, hats, napkins, twine, washbowls, pails, spittoons, carpets, car wheels, etc. This, together with the improvements in the printing

presses, and especially the introduction of the Walter press in 1868, whereby paper could be printed in a roll at a much more rapid rate, demanded not only a large increase in the supply of paper, but paper made of a new material, one that would receive and absorb readily the quick-spreading ink. It was at this period that the much-mooted wood pulp came upon the stage. Previously little else had been used in this country for paper except cotton and linen rags and some straw. The introduction of the new material, though demanded, was looked upon with suspicion both by the paper manufacturer and consumer. The prejudice against any known substitute for rags was very strong, and it was with difficulty that the first newspapers were persuaded to give it a trial.

Mechanically made pulp is ground on an ordinary grindstone. The cellulose, starch, and other kindred elements are precipitated into pulp, and go directly into paper. This gives it a readily absorbent quality, a kind of paper which the rapid printing presses require. In fact, they would be absolutely helpless without it.

Chemical wood pulp, so called, is also largely manufactured in this country, and finds its way into a finer grade of paper, book, and writing papers. This pulp is produced by reducing the wood mechanically into small chips, and then boiling them with caustic alkali until the cellulose is rid of the starch and earthy matter which surrounds it, leaving the pure fiber.

Another step has recently been made in the production of chemical pulp by reducing it by an acid solution, etc., bisulphite pulp, so called, and a stronger fiber is obtained.

There is now manufactured in this country daily about 450 tons of mechanical pulp and 250 tons of chemical pulp. As each ton of this pulp represents about the same quantity of manufactured paper, it represents about double the quantity of old rags, as they shrink in working about one-half, so that, without this material, it would be impossible to obtain a sufficient quantity of rags to make the paper now consumed.

The price of paper has been very materially reduced by the introduction of wood pulp. Before the war the current price of newspapers was nine cents per pound; during the war it ran up to twenty-five and twenty-eight cents per pound. It has gradually fallen until now the ordinary newspaper is worth about 4½ cents, and book papers are in the same proportion.

There are about 200,000 cords of wood ground into mechanical pulp, and about 150,000 cords consumed by the chemical process. The two principal woods used for this purpose are poplar and spruce.

At the close of Mr. Russell's paper the President introduced Prof. L. M. Norton, of the Institute, who read a paper on

NATURAL GAS.

Prof. NORTON said: In all manufacturing operations the question of fuel is one of preëminent importance. Cheap and abundant fuel often governs the location of new industries. During the last two or three years we have heard of the introduction of a new fuel in a portion of our country, and I ask your attention for a few moments to the composition and fuel value of the natural gas.

In what form is fuel most convenient? The solid form is most common, but the uses of fuel in that form are open to many objections. The cost of handling is large, and the shrinkage is considerable. The cost of removing ashes and slag is not to be left out of account. When the coal reaches the boiler room, the firing is expensive, the deterioration of the boiler is often made rapid by improper management, while the difficulty found in obtaining any large per cent of the energy present in coal is great. The air supply must be regulated with the utmost care on all portions of the grate if any really satisfactory results are to be obtained. What is true of coal is true of all solid fuels.

Liquid fuels are capable, in certain localities, of giving good results. There is, however, a considerable shrinkage in transportation. But the worst difficulty in connection with the use of liquid fuels arises from the necessity of storing large quantities of inflammable liquids in cities and near factories. For this reason it does not seem probable that such fuels will ever find a very wide application. The combustion of oils can be made very complete, and a figure approaching the theoretical energy obtained. Although it can be easily regulated, oil requires constant watching when used as a fuel.

It must be evident to all that a gaseous fuel fulfills all the requirements of an economical fuel. It is free from residue, the storage can be at a convenient distance from other property. The regulation can be perfect, and the air supply can be governed so that

a high per cent of the total average can be obtained. The advantages of a gaseous fuel are so great that many species of plants are in existence which are used to convert solid into gaseous fuel.

Nature, however, has accumulated vast stores of such fuel in the crust of the earth. This natural gas consists of hydrocarbons, and these under pressure, perhaps, permeate a considerable portion of the earth's crust. Where this state of things exists, a hole bored into such a stratum removes the pressure, and the gas rushes out, perhaps traveling for miles through the roots to reach the opening. I shall not consider this question from the geological point of view, and in regard to the origin of the gas I can only say that no satisfactory theory has yet been proposed, but there seems to be no reason to suppose that the agencies which formed this gas have ceased to act or that they are limited to small areas, so that the chance of immediate exhaustion of the gas is very small.

The composition of the gas from various localities varies through certain limits.

The analysis presents great difficulties. The hydrocarbons present are mainly methane and ethane. Hydrogen is undoubtedly present in many of the gases.

The best gas equals theoretically per 100 cubic feet of gas, weighing 4¼ pounds, on an average eight pounds of carbon. Anthracite contains 90.93 per cent of carbon, so that 100 cubic feet of gas will equal in theoretical fuel value about nine pounds of anthracite.

Now, the practical fuel value, of course, varies according to the pattern of the boiler or combustion chamber, but I was told several times during my stay in Pittsburg that the available fuel value favored the natural gas. I have never been able to obtain any really satisfactory figures on this point, but it is safe to put the fuel value of one hundred cubic feet of gas, with a hot blast of the generative system, as equal to twelve pounds of steam coal, while the expenses attending the use of the gas are very small in comparison with those attending the use of the coal. It is a somewhat peculiar experience to approach Pittsburg in the early morning and find the gas burning in the village lamps. They never extinguish it. It is a novel sight to see a boiler room as clean as an engine room, and huge jets of gas underneath the boilers, controlled by valves, and one fireman for a half dozen great boilers, and that one reading a paper.

Domestic arrangements are given a convenience beyond all conception. There is a fire in the range only when it is needed. Servants refuse to live in houses where the gas is not present.

Natural gas is indeed a marvel in a marvelous age.

The President extended the thanks of the Society to the speakers, and the meeting was adjourned.

MEETING 372.

Standards of Length, and their Practical Application.

BY MR. GEORGE M. BOND.

The 372nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 1st, at 8 P. M., Prof. Gaetano Lanza in the chair.

After the reading of the records of the previous meeting, the chairman introduced Mr. George M. Bond, of Hartford, Conn., who read a paper on "Standards of Length, and their Practical Application."

Mr. BOND said: The subject of standards for weights and measures has received consideration by every nation, both by common consent and by legislative enactment, from the earliest history of the world to the present time, and though crude as may have been the earlier standards to which were referred the weights and measures of every-day life, the fact remains indisputable that some definite, arbitrary, or fixed distance or weight, determined as accurately as the times or the conditions would permit, has ever been agreed upon and tacitly accepted as an ultimate means of settling differences of opinion in this regard; while the willful use of false weights or measures has universally, and from time immemorial, been held up in righteous indignation and contempt by all who possess a just regard for truth.

The factor of linear measure enters primarily into every problem of cubical contents or of volume, and in the determination of standards of weight, which is illustrated in the units adopted under the metric system of weights and measures.

As is well known, a gramme is the weight in vacuo of a cubic centimetre of distilled water at the temperature of maximum density, or about 4 degrees C., and a litre is equal in volume to a cubic decimetre, the latter being in linear measure one-tenth of the metric unit of length, the metre. Long before this system had an existence or even a name, the standard of weight of Great Britain has been the Troy pound, from which was copied the Troy pound used in this country, and which is defined as the weight of 22.794,422 cubic inches of distilled water at its maximum density (at a temperature of 39 degrees F., nearly), the barometer standing at 30 inches, while the standard pound avoirdupois, used as the commercial unit of weight in Great Britain and the United States, is the weight of 27.7015 (nearly) cubic inches of distilled water at a temperature of 39.2 degrees F., the barometer being taken at 30 inches, at the latitude of London, its maximum density at this place, and is equal to the weight of 7000 grains, a grain being the smallest unit in English tables of weight, and identical for both the Troy and avoirdupois pounds.

Under the authority of Kater, one cubic inch of distilled water at 62 degrees F. weighs 252.456 grains, the barometer also being taken at 30 inches; the standard inch for this determination being 1-36 of the Imperial yard, the latter derived from the length of a pendulum vibrating seconds of mean time in a vacuum at the level of the sea, at the latitude of London or Greenwich.

The ancient standard of weight in England was the grain, so called from being measured by the weight of a thoroughly dried grain of wheat taken from the middle of the ear, and this unique natural unit is perhaps no older than the table of English "long measure — three barley corns make one inch," these being placed end to end to form the basis of a standard of measurement for a nation!

We also find that the length of the arm of King Henry the First was considered the correct basis for a standard system of measurement, while earlier the human foot or the hand came in for their share in the effort to establish a standard of length for ultimate reference.

In ancient times, among the Greeks, at the institution of the Olympic games by Hercules, his foot is said to have been substituted for the ancient cubit, probably approaching it very nearly in size, as a unit of measurement for the foot races held at that time, and six hundred of them constituted the stadium or length of the course, and thenceforth became the standard of that nation.

This unit was afterwards by the Romans combined with the pace, a thousand of which constituted the mile. It is curious to note that to this day the foot and the mile are our common standard measures of distance.

The weights and measures in use in Burmah at the present time are of a very indefinite character, and compare favorably with the early English standards of the barley corn and the foot; for distances, as described in the *British Burmah Gazetteer*, are designated as a "call," or about 200 yards; "the sound of a gunshot," or about half a mile; a "stone's throw," or from 50 to 60 yards; "breakfast distance," or as far as a man would be likely to walk before breakfast time, — say one hour, — all derived from the every-day life of the people, and are as vague in their exactness as such distances might be supposed to result from the use by multiplication of "three barley corns, round and dry," placed end to end, to serve as a unit of measurement, the so-called standard inch.

No less than thirteen different lengths of the so-called standard foot (pied) in legal use have existed, varying from 120 to 150.5 lignes; and eighteen different legal yards (aunes), measuring from 299.8 to 597.2 lignes, the "ancien ligne" being equal to 0.0888 inch.

We find also among the records of the search after a true standard as great a range of value for the foot as that of the Pythic of 9¾ inches to that of Geneva of 19 inches, including the standard foot of Milan, which is 15.62 inches.

Under the general theory of measurement, most of the quantities for which measurements are needed can be expressed by means of three conditions: first, a definite length; second, a definite mass; and, third, a definite interval or unit of time.

The scientific system most admirably covering these conditions is that suggested by the Units Committee of the British Association, using the metric standards of length, volume, and weight, but using the time-honored unit of duration, the second; in which system

the unit of length is the centimetre, the unit of mass the gramme, and the unit of time the second, being referred to for the sake of brevity or simplicity as the C. G. S. System. (See *Enc. Brit.*, ninth ed., vol. xv, p. 668.)

The standard inch is the thirty-sixth part of the Imperial yard derived from the length of a pendulum vibrating seconds, thus introducing the condition of time, and the length of such a pendulum was by Act of Parliament, June 17, 1824, declared as being 39.1393 inches; the yard to be made up of thirty-six of these standard inches.

The Act legalizing this standard reads as follows: —

SECTION I. — Be it enacted . . . . . that from and after the first day of May, one thousand eight hundred and twenty-five, the straight Line or distance between the Centers of the Two Points in the Gold Studs in the straight Brass Rod, now in the Custody of the Clerk of the House of Commons, whereon the words and figures "Standard Yard, 1760," are engraved, shall be and the same is hereby declared to be the extension called a Yard; and that the same straight Line or Distance between the Centers of the said Two Points in the said Gold Studs in said Brass Rod, the Brass being at the temperature of Sixty-two Degrees by Fahrenheit Thermometer, shall be and is hereby denominated the "Imperial Yard" . . . .

SECTION III. — And whereas it is expedient that the said Standard Yard, if lost, destroyed, defaced, or otherwise injured, should be restored to the same length by reference to some invariable natural Standard; And whereas it has been ascertained by the Commissioners appointed by His Majesty to enquire into the subject of Weights and Measures, that the Yard hereby declared to be the Imperial Standard Yard, when compared with a Pendulum vibrating Seconds of Mean Time in the Latitude of London in a Vacuum at the Level of the Sea, is in the proportion of Thirty-six Inches to Thirty-nine Inches and one thousand three hundred and ninety-three ten-thousandths Parts of an Inch; Be it therefore enacted and declared, That if at any Time hereafter the said Imperial Standard Yard shall be lost or shall be in any Manner destroyed, defaced, or otherwise injured, it shall and may be restored by making a new Standard Yard, bearing the same proportion to such Pendulum as aforesaid, as the said Imperial Yard bears to such Pendulum.

The calamity, for which event the carefully worded section III. was intended to provide, happened ten years afterwards, and was the destruction of the Standard Yard by fire, when both houses of Parliament were burned. In the attempt to reproduce the standard under the provisions of the Act it was finally restored by making its value equal to the mean of the copies then in existence. It was proved that there were errors in the determination of the specific gravity of the pendulum employed and in the other elements involved.

The metre of the Archives was made a legalized standard after all attempts were abandoned to make it conform to the natural unit. It is Standard at 0 degrees Centigrade, or 32 degrees Fahrenheit.

Another natural unit which has been proposed as the basis of a standard of length is the length of a wave of monochromatic or single color light. We are all familiar with the beautiful colors so wonderfully arranged in the thin film of a soap bubble, and in order to briefly explain the cause of the "interference" of the different wave lengths which produces this beautiful effect, we should remember that light is made up of seven distinct colored rays, which blended together produce clear white light. Each of these separate rays has an undulatory or wave motion through space, from their source, the sun, and the length of a wave, or the distance from the top of one wave to the crest of the next, is different for each as compared with those of unlike color, but always constant for its own; that of the green ray, for example, being computed equal to about 1-50,000 of an inch from crest to crest. The objection to this unit is that the addition or multiplication of such minute units for the purpose of obtaining a practical standard of length might introduce errors in the total greater than would be likely to result from either of the methods already mentioned.

The use made of this unit seems to confirm the theories in regard to the limit of the ultimate divisibility of matter, and these same soap bubbles have shown a way in which to estimate scientifically the dimensions, approximately, of a molecule, a form of matter so minute that the smallest object visible under the most powerful microscope is made up of countless numbers of them.

It has been demonstrated that the mechanical energy required to pull apart the molecules of water in forming steam is no greater, according to the theory of capillary action, than is required to reduce

the thickness of a film of water to the 1-500,000,000 of an inch; a force quite large when compared with the small amount of water which we are considering. The measurement of this minute thickness is based upon the varying colors exhibited in the soap bubble, using the length of any given wave. Probably before this extreme tenuity could be attained, there would remain only a single layer of molecules held together by their mutual attraction, giving as the estimated average diameter of a molecule the 1-500,000,000 of an inch, a dimension so infinitely minute as to be quite beyond our ability to realize.

Sir William Thomson, from a comparison of these phenomena, has estimated the limits of range or size of these minute molecules to be between 1-250,000,000 and 1-500,000,000 of an inch, and in order to give some conception of the "coarse grainedness," as he calls it, thus indicated, he has said that "if we conceive a sphere of water as large as a pea, magnified to the size of the earth, each molecule being magnified in the same proportion, the magnified structure would be coarser grained than a heap of small lead shot, but less coarse grained than a heap of cricket balls."*

The materials available for standards of length, taken in the order of the rate of their expansion under the same conditions of temperature, are wood, glass, platinum, gold, silver, iron, brass, and copper. Wood may be rejected at once for our purpose, though it does very well for yard-sticks and pocket-rules for every-day use. Glass has been and is now used in certain cases, though its great brittleness restricts its application, and the changes going on within its structure are now the subject of rigid investigation by Prof. Rogers, requiring time to prove its value as a material for standards.

Platinum was adopted as the material for the end-measure *Metre des Archives*, and also for the bars representing the line and end metre standards in Great Britain.

Gold and silver may be said to be excluded for various reasons, that of cost in the case of gold, and its extreme softness, and silver, because of its great affinity for sulphur.

The Russian standard of length, used for geodetic surveys, was constructed of iron, using conical pieces of tempered steel in each end. This bar has a length of seven feet.

* *How Molecules are Measured.* By Prof. Josiah P. Cook, of Harvard College.

The late M. Tresca, Acting Director of the Conservatory of Paris, constructed a copper bar, a line metre, of a form which he originally proposed. The bar is "X" shaped, very light and strong, and has the defining lines of the metre ruled on a plane midway between the top and bottom edges.

To show one of the methods adopted for comparing the standard yard or metre bars, the "Rogers-Bond Universal Comparator" was described. This instrument of precision was constructed during 1880–1881 by The Pratt & Whitney Company, of Hartford, Conn., from plans proposed by Prof. William A. Rogers, who at that time was connected with the Observatory of Harvard College, and was designed for the purpose of comparing and investigating standards of length, and for permanently establishing standard gauge dimensions, in order to fulfill the requirements of modern machine-shop practice.

The Comparator used by The Pratt & Whitney Company provides means for the direct comparison of the transfers of the yard and metre bars furnished by Prof. Rogers, and also for the investigation of the sub-divisions of these transfers, which are the basis of all the standard gauges now made by its use.

In order to use a microscope upon lines ruled on polished surfaces, or on any opaque material, some means for obtaining sufficient light must be employed in order to see them distinctly, without the use of reflectors, which are often a source of error in standard work.

The tubes of the two microscopes are twelve inches long and one and one-fourth inches diameter. The eye-piece micrometers were made by Joseph Zentmayer, of Philadelphia, whose skill as an optician is too well known to require further proof of their excellence. The objectives were made by the late Mr. R. B. Tolles of this city (Boston), and are each fitted with his illuminating prism, made of perfectly clear glass, placed just above the lower lens, one end of the prism passing through the side of the objective. The inner end of this prism is beveled, forming an angle of the end surface with respect to the axis of the prism, such that the light is refracted perpendicularly upon the surface of the bar, so that lines less than 1-30,000 of an inch in width are easily seen and separated with a one-inch objective.

The "stop method" is to compare a line-measure or an end-

measure bar, on each side of the center line of motion of the microscope plate, using one microscope, and comparing this fixed length with the constant quantity before referred to, which is the distance between the stops. Should the path be a curved one, the distance between the defining lines upon the bar will appear greater on one side than on the other in proportion to the amount of curvature existing. By means of the proportion of similar triangles thus formed, the lengths of the radii may be very accurately determined. By placing different standards on one side of the line of the stops, they may be, by being compared with a constant quantity, compared also with each other.

The subdivision of these standards of length is effected by the use of this same process,— the microscope plate sliding between fixed stops,— and which serves to beautifully illustrate one of the fundamental principles of science, that "things equal to the same thing are equal to each other," or that the relation of different lengths each to a constant distance establishes their relation to each other.

The foot may then be subdivided in the same manner into twelve equal parts, establishing the standard inch, and, further, to eighths, sixteenths, thirty-seconds, hundredths, or even to thousandths of an inch.

To illustrate this method, and to make plain the reason why these corrections so obtained are used, we can suppose a case of simply dividing a rod or a string into two parts. Now, we know that for whatever amount one part is longer than the other, one-half of this amount belongs to the shorter to make it exactly one-half the whole length of the rod or string; hence we have one-half the sum, or amount, of the difference, and subtracting each difference from this half sum would in one case give us a minus correction for the longer part, and a plus correction to be applied to the shorter. The yard has thus been subdivided within a limit of about one hundred-thousandth of an inch.

The necessity for the correct solution of this problem arose from the requirements of the Master Car Builders' Association, through their committee appointed to investigate and report as to the degree of accuracy desirable to be secured, and the best means of maintaining this accuracy in the standard thread, which was proposed by Mr.

William Sellers, and afterwards adopted by the Franklin Institute, and adopted by the Association at their convention, held in Richmond, Va., June 15, 1871.

Mr. M. N. Forney was chairman of this committee, and there is certainly due to him and to Mr. Chanute, who at that time was connected with the Erie Railway Company, much of the credit for the successful termination of this important work.

The Pratt & Whitney Company, having been commissioned to execute for the Association their order for a standard set of reference thread gauges, was brought through the aid of Prof. James E. Denton, M. E., of the Stevens Institute of Technology, into communication with Prof. Rogers, at the time he was engaged in the work of obtaining transfers of the standards abroad.

In describing the method of applying these finely-ruled standard subdivisions to the practical work of measuring working gauges, the caliper attachment to the comparator furnishes a reliable and efficient means by which the subdivisions ruled on hardened steel, representing aliquot parts of the standard yard, are transferred to tangible gauge dimensions, resulting in obtaining standard uniformity and interchangeability within a limit of accuracy not possible by the ordinary duplicating methods, or the use of the micrometer or vernier slide gauge. The element of probable wear of a set of reference gauges, necessary under the ordinary method of duplication, is entirely eliminated. For, however carefully an original set of gauges may have been adjusted to standard size, their continued use and the effect of time upon hardened steel, should they be made of this material, will sooner or later affect their standard qualities, and lead the tool-maker farther and farther away from the standard sizes which he may have had originally.

To use this line measure standard bar, the bar is placed with its upper surface in a horizontal plane, below the microscope in the rear of the pair with which the comparator is fitted, and in focus the entire length when the microscope is carried over it by the sliding plate which rests upon the rigid cylindrical ways of the comparator. The other microscope is then focussed on a finely-ruled line which is upon a little hardened steel plate having a polished plane surface, this plate being attached directly to the sliding cylindrical bar or plunger, shown in the view upon the screen.

By carefully setting the eye-piece micrometer line in coincidence with the initial line of the standard bar, and also upon the line on the plate referred to, with a definite amount of pressure exerted upon the surfaces of the "stops" or abutting faces, which are polished planes, by a spring contained within the plunger, a positive "zero" or starting point is obtained. This invariable initial position being thus secured for each size of gauge to be measured, it is only necessary to place between the faces of the stops, with the same amount of pressure, the gauge to be operated upon, and moving the plate until the rear microscope is again in coincidence with the line representing the required dimension, the correctness or variation is at once indicated within a limit of about 1-50,000 of an inch, the line upon the little plate being only about 1-25,000 of an inch in width, and the micrometer reading, being taken readily within one-half of this minute quantity, gives some idea of the rapidity as well as the accuracy of this method when applied to the inspection of size gauges which are to represent when finished standards for reference in actual practice in the tool room for every purpose where interchangeability is desirable.

The standard line-measure bar used in this connection is designated as P. and $W._5$ in the report of Prof. Rogers to the company, and has a correction in total length, at 62 degrees F., of only five millionths of an inch, while the correction for the greatest error in any subdivision is only 1-50,000 of an inch. It is made of hardened steel, and thus can be used to measure hardened steel gauges at any convenient temperature, providing, of course, that a constant temperature has been maintained for a time previous sufficiently long to ensure uniformity for both bar and gauge.

The production of the model set of standard gauges for the Master Car Builders' Association included the origination of a "master triangle," in order to make the proper gauges for the correct angle of the United States Standard thread. The object in view was to furnish a means of obtaining a triangle of definite size, which should be exactly two inches long on each side, and being equilateral must be equiangular; and being equiangular must consequently be one having angles of 60 degrees. The reason for having the sides just two inches long was that it was necessary to establish the width of the flat for each pitch of the various sizes of the Franklin Insti-

tute thread, each being one-eighth of the pitch, so that for a thread of two inches pitch the flat should measure just one-quarter of an inch.

(Working gauges were shown of hardened steel, which were made standard within a limit of about 1-50,000 of an inch, and thus perfectly interchangeable.)

As to the effect of the liability of change of size of a hardened steel gauge, due to age or other conditions, an instance was shown of the breaking of such a gauge, caused by the excessive internal strain in the sudden contraction of the outside during the process of hardening with a subsequent enlargement of the contracted ends. It is noticed in the ends of standard cylindrical gauges, after they have been made for a year or eighteen months, that they are sometimes found to measure about 1-20,000 to 1-10,000 of an inch smaller just at the extreme end, where the steel is no doubt the hardest. This difficulty is avoided by actually "seasoning" the gauges before final finishing, together with special operations in the working and hardening of the steel itself.

In the endeavor to bring about practical standard uniformity in the sizes of wrought iron pipe and pipe threads, it may be here stated that the initial steps in this important matter were taken during the sixth annual meeting of the American Society of Mechanical Engineers, held in this city in November, 1886, in this very building, a committee having been at that time appointed to investigate and report regarding it.

The action of the American Railway Master Mechanics' Association, at their annual meeting held in this city, in June, 1886, in adopting definite standard sizes for the diameter of locomotive driving-wheel centers and tires, is another important step in the direction of practical uniformity. By reducing the number of sizes to six, covering the range of diameters ordinarily used, these being represented by definite standard reference gauges, the proper steps have been taken to secure the same advantages in lessening the detail and cost in this respect, in the construction of locomotives, as it is already appreciated in regard to standard interchangeability of bolts and nuts, serving to extend the application of the principle of practical standard uniformity and consequent interchangeability, which is, "cheapness, serviceableness, and quantitative accuracy."

MEETING 373.

Chemical Examination of Drinking Water.

BY PROF. T. M. DROWN.

The Johnson Heat-Regulating System.

BY. MR. WM. F. CHESTER.

The 373rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 22nd, at 8 P. M., Dr. H. P. Walcott in the chair.

After the reading of the records of the previous meeting and the election of new members, the chairman introduced Prof. T. M. Drown, of the Institute, who read a paper on "Chemical Examination of Drinking Water."

Prof. DROWN said: The result of the chemical analysis of a drinking water, as ordinarily expressed, cannot be said to carry its explanation with it. The layman notes simply that the figures express very minute amounts of substances which are generally unfamiliar. And when he is told that none of the substances are necessarily injurious in themselves, and, moreover, that a good water may, under certain conditions, give numerical results which are identical with a bad water, his faith in the value of a chemical examination may well be shaken.

Three elementary considerations must be borne in mind in discussing the question of a water supply for drinking purposes: —

1. There are no absolutely pure waters to be obtained in nature.
2. The impurities found in natural waters differ widely in character when considered from a sanitary standpoint.
3. The same impurity may have a varying sanitary significance according to its origin.

An illustration of this is offered in the following analysis: —

ANALYSIS OF A DRINKING WATER.

PARTS IN 100,000.

Turbidity	distinct.
Sediment	slight.
Color	0.35 (a light-yellowish brown).
Odor, cold	distinctly disagreeable.
Odor, hot	" "
Total solids	4.85
Loss on ignition	1.17
Fixed solids	3.68
Odor on ignition	strongly peaty.
Free ammonia	none.
Albuminoid ammonia	0.0224
Nitrogen as nitrates	0.0050
Nitrogen as nitrites	none.
Chlorine	0.43

This is the analysis of a sample of water (taken in the month of November) which is supplied to a large city. It is not attractive in appearance, and its odor is at times repellent. To an experienced water analyst this analysis suggests at once the origin of the water. He would say, without hesitation, that it was from a pond or lake, possibly from a river, and that the analysis revealed nothing necessarily injurious. If told that it came from a well, he would with equal promptness declare the water suspicious, and probably unfit for drinking, for no normal well water ever has an appearance and composition like this.

Chemical analysis often indicates previous pollution which it does not actually detect as such, and its results to have their highest value must be associated with the physical facts relating to the origin, progress, and environment of the water.

Our supply of water depends entirely on rain. The kind of surface upon which the rain falls determines the course of the water and the rate and conditions of its flow. In rocky regions the water forms rapidly-moving streams; on peaty or loamy soil a part of the water flows on the surface and a part soaks into the ground; on porous, sandy soil the greater part of the water may at once disappear from sight into the sand. In any case, the water seeks lower

and lower levels until it flows into the sea. Some of it never reaches this destination; a portion of the surface water returns to the atmosphere directly by evaporation; a portion of the ground water evaporates through the intervention of plants; and another portion is retained in porous rocks, and enters into mineral combinations.

Our attention will be first claimed by the surface waters. When a rapidly-flowing brook passes over a rocky surface it has but little opportunity to dissolve either mineral or organic matter, and mountain water of this character is universally recognized to be of the highest purity. As it continues its course it may pass through a forest with a much diminished rate of flow, and dissolve the coloring matter of leaves and peat, and also some mineral matters which are in the soil. We see it again flowing over swampy ground into an obstructed valley, and thus forming a lake. Under these conditions of very gradual, almost imperceptible, movement there is opportunity offered for the growth of many plants and animal organisms which do not thrive in rapidly-moving streams, and the water acquires from these growths, perhaps also from their decay, a decided taste and odor, and acquires a still more pronounced color. Flowing from the lake, as a river of increased size, it passes through a highly-cultivated farming region in which there is a deep, loamy soil, well manured. This will contribute to the water matter of animal origin in a condition of advanced decomposition. Further, as it flows past villages and towns it receives the refuse products of human life, which we include under the general name of sewage, and also the waste products of slaughter houses, tanneries, dye works, and factories of various kinds, which contribute not only putrefying material but also mineral substances of various kinds.

If we turn now to the study of the progress and character of the waters below the surface, we find a very different condition of affairs. The water which sinks into a porous soil during a rainfall descends slowly downwards until it reaches the level of the water already existing in the soil, or until it reaches an impervious layer of rock or clay. There is water present in most porous, gravelly, and sandy soils which is slowly flowing onward to lower levels. Its motion is not perceptible to the eye, but it can easily be measured. It is this mass of water which we intercept and utilize in the shallow, household well, as well as on the large scale where numerous wells

are driven into this porous stratum to furnish the water supply of cities. When this water finds a natural outlet on a hillside or in a valley, we call it a spring. Many rocks are porous and cellular, and retain considerable water; when wells are sunk into these rocks, they yield a plentiful supply of water and are known as deep wells, or rock wells. Rain falling on rocks full of cracks and fissures, or ground water flowing over rocks of this character, may descend to very great depths before reaching an impervious layer, and be under considerable hydrostatic pressure. By boring we may strike this water and have a flowing, or artesian, well. If it finds a natural outlet, we call it a rocky spring, to distinguish it from the surface springs in porous soil. All these varieties of ground water are characterized by their freedom from organic impurity, and by a large quantity of mineral matter which their long contact with rocks and soil have enabled them to dissolve. If much lime and magnesia have been dissolved, we say the waters are hard.

Before discussing further the character of natural waters and their fitness for drinking, it will be necessary to review briefly the methods employed in analyzing a water, and explain the meaning of the results as ordinarily expressed.

An inspection of the water in a large white-glass bottle will reveal the degree and kind of permanent turbidity, — that is, the light particles of clayey or vegetable matter which do not settle to the bottom on standing, and also the amount and kind of the sediment which has been deposited. To learn the exact nature of the suspended matter and of the sediment a microscopic examination may be necessary. The odor should be noted by shaking up the water in the bottle when it is about one-half or two-thirds full, and then smelling of the enclosed air. Then the water is heated nearly to boiling, and the odor again noted. Much information with regard to the nature of the dissolved and suspended matter can be obtained in this way.

The color indicates approximately the amount of dissolved vegetable matter. As a convenient measure for comparison, it may be said that Cochituate water as drawn from a tap has usually a color of about 0.3 or 0.4 on the scale used in the analysis of waters for the Mass. State Board of Health. On the evaporation of a portion of the water to dryness, we get a solid residue which we call the "total

solids." This means all the dissolved matter, both mineral and organic, and also the suspended matter if the water is turbid and not previously filtered. On heating this residue to redness we burn off the organic matter and obtain the "loss on ignition." Unfortunately, this heating may, in many cases, drive off some of the mineral contents as well as the organic, and this loss, as ordinarily obtained, does not give us even an approximate determination of the organic matter. Still, in surface waters, with low mineral contents, we can, by carefully controlling the conditions of the ignition, obtain a very fairly accurate determination of the organic matter in this way.

The "fixed solids" are obtained by subtracting the loss from the total solids. It represents the amount of mineral matters; but, as already implied, this determination is generally too low, on account of the loss being too high. These mineral matters consist mainly of sulphates, chlorides, carbonates, and silicates of the alkalies and alkaline earths. Chloride of sodium (common salt) is present in all waters, being dissolved from rocks and soils. Its amount is generally small, and when, therefore, we find it in large quantity, we suspect the presence of sewage, or the waste products of human life, which always contain a large amount of salt. In any case, therefore, of unusually high chlorine an investigation is called for into the source of the water to ascertain whether this chlorine came from rocks or soils naturally high in chlorine, or from salt blown inland from the ocean, or whether the salt used in domestic life was its source.

Broadly speaking, living matter has the power of converting inorganic substances into organized structures, but when the life is extinct then the organized matter reverts, by process more or less complicated, into the inorganic condition. For our purpose it will suffice to consider the organic matter we find in water to be compounds of carbon, hydrogen, nitrogen, and oxygen. In the process of decay the nitrogen is converted into ammonia, and ultimately into nitric acid, which combines with some of the bases present, — potash or lime, — forming what we call, in a general way, nitrates. These two substances, ammonia and nitric acid, are so easily detected and quantitatively determined, even when present in very minute quantities, that we use them as the basis of our investigation into the nature of the organic matter and the extent of the changes which it has undergone. Suppose we examine a water and find no

ammonia, what does this indicate? That the water contained no nitrogenous compound from which ammonia could be formed; or that the nitrogen which it originally contained has been completely oxidized to nitric acid; or, perhaps, that the ammonia is oxidized as quickly as it is formed, or, again, that the ammonia has been absorbed by the soil, and thus removed from the water. It is important to distinguish between ammonia ready formed and the nitrogenous matter which is capable of developing ammonia. In any given sample of water taken from a lake or river we may find nitrogenous matter in many conditions. First, as living plants and animals; second, as dead organisms which have not yet begun to change; and, third, organic matter in all stages of putrefaction. By chemical means we can convert nitrogenous matter into ammonia very quickly, completing changes in a few minutes which might take many days or weeks under ordinary, natural conditions.

In one of the most used methods of water analysis we determine by a simple process of distillation the ammonia which is ready formed in the water, and then the amount of ammonia which the remaining nitrogenous matter is capable of developing. We call these respectively "free ammonia" and "albuminoid ammonia." The latter term is arbitrarily given, and was suggested by the fact that albumen gives ammonia under the same chemical treatment. This distinction between the nitrogen which has already passed into the condition of ammonia, and the nitrogen which still exists in its original organic condition, is an important one. The latter, or albuminoid ammonia, expresses in a general way the amount of nitrogenous matter in the water which is still capable of undergoing putrefactive change. But just here the method is defective: the albuminoid ammonia tells the *possibilities* which exist for decay, but tells us very little as to the *probabilities* of this change taking place in the natural course of events. What we really want to know is the nature of this nitrogenous matter, and our chemical process simply tells us how much nitrogen there is present. It is true that there are certain indications which we get in the course of analysis which throw some light on this subject, but it is a very feeble and uncertain one. The greater stability of vegetable matter, or its less susceptibility to decay as compared with animal matter, enables us often to distinguish between these two classes of nitrogenous matter. If, for example, we examine

a sample of water at intervals of weeks or months, taking out a portion from time to time, and exposing the remainder to ordinary atmospheric conditions in the intervals, we can find out its rate of change. If we find that this rate is slow, or that there is no change at all, during a month or more, no development of free ammonia, and that the albuminoid ammonia remains constant in amount, then we may fairly conclude that the nitrogenous matter in the water is of vegetable origin. This is a condition of affairs that we often find in the brown waters of lakes and rivers which are uncontaminated with animal matter; or, if they were originally thus contaminated, then the animal matter has completed its changes consequent on decay, and disappeared as such from the water.

The final stage of the oxidation of organic matter is indicated when the nitrogen exists entirely in the form of nitric acid. There is an intermediate stage between ammonia and nitric acid, namely, nitrous acid, which combines with bases to form nitrites. It is possible that the formation of nitrous acid is not always in the line of progression to nitric acid, but that it may be also, at times, the result of a retrograde action from the action of organic matter on nitric acid, a condition of things which, when existing, it is of great importance to recognize. Until quite recently it was supposed that the direct action of the oxygen of the air, and of that in solution in the water, were the causes of the changes which have been described. But we now know that these changes are the indirect result of the vital action of minute organisms — bacteria — which feed on the organic matter, and in some way effect this change of the nitrogen into ammonia and nitric acid. Their activity is greatest in the soil near the surface, and in warm weather, and it is therefore in ground waters that we find the largest development of nitric acid and the most complete obliteration of the organic matter. The nitrates in river water, and in surface waters, are not generally high. Whether this is due to the fact that there are relatively fewer bacteria to the mass of water, or to their feebler activity in the light, or, again, to the fact that the nitrates formed are promptly absorbed by vegetable or animal growth in the water, cannot be said with certainty.

The practical question now arises, what do we actually learn from a chemical analysis as to the fitness of a water for drinking? The answer to this has already been intimated, namely, that a chemi-

cal analysis taken in connection with a knowledge of the origin, progress, and environment of the water will enable us to say what has been the extent and nature of the pollution, what has been the extent of its purification since it was polluted, and what is its present condition.

It is necessary to have some clear idea what we mean when we say that a water is fit or is not fit for drinking. The presence of organic matter cannot, *per se*, be regarded as injurious, for our life depends on the assimilation of organic matter. It is rather the nature and condition of the organic matter that is of significance. The causation of disease by drinking water is at present an unsettled subject of controversy, and we will confine ourselves to the statement of a few facts that will meet with general acceptance.

The germs of some diseases are transmitted by water, and when this water is used for drinking these germs may reproduce the disease. Typhoid fever is thus disseminated when the refuse of a town, or even of a single house in which typhoid fever exists, is thrown into a stream.

Again, the presence of sewage in a stream has the tendency to promote the death rate of a city using this water for drinking. The change in a water supply of a city from a polluted stream to purer water has generally been followed by a lowering of the death rate. Why this is so we do not certainly know. It may be the direct action of the decomposing matter causing a general depression of the vital forces; or some of the products of decay may be in themselves distinctly poisonous; or it may be the result of the action of specific morbific germs which accompany some forms of decaying matter; or, again, it may be in consequence of the excessive number of micro-organisms, which in moderate number may be harmless. Speculation may here easily run riot in absence of positive knowledge. But so much seems to be safe to say, namely, that it is not a good thing to drink water which contains organic matter of animal origin undergoing decay, which is the natural process of change from organized forms into inorganic combinations. The two extremes of organized matter and mineral matter we may take without fear, but the state of change is in some obscure way a state of danger. Whether this applies equally to decaying vegetable matter is not certain. There is strong evidence indicating that the conditions are very different,

and that we may have a large amount of dissolved vegetable matter in water without danger to health. This, however, applies only to vegetable matter derived from natural sources, and not to those derived from manufacturing operations. It looks as if the danger was in direct porportion to the *activity* of the change. Now, we know that many of the dark-brown waters which owe their color to vegetable matter are often very permanent, with no tendéncy to change on long exposure to the atmosphere. Under such conditions the bacteria of decay cannot be very numerous or active. This brown matter in solution in water yields, in the course of chemical analysis, "albuminoid ammonia," but it has probably no sanitary significance. There is more "albuminoid ammonia" in one cup of tea than in many gallons of a dark-colored pond water.

I have purposely omitted any reference to the mineral matter in solution in drinking waters. When this is excessive, the water has a distinct saline taste, and such waters are generally classed as mineral waters and reserved for medical use. Disregarding this class of waters, we may say that what we want to avoid in a drinking water is sewage, using the term broadly to mean the refuse products of human life and manufacture. Is a river which receives sewage at *any* point unfit for drinking for the rest of its course? How much impurity may remain in the water without its rejection as a drinking water? How far must a well be from a house or stable to be permanently safe? These are every-day questions, fair questions, too, to which an answer should be given, although it is impossible to answer them in the same brief compass in which they are asked.

It is reasonable to suppose that a small amount of pollution is not as dangerous as a large amount, and that great dilution of the polluting material may render it practically inappreciable. Thus, the sewage of Minneapolis and St. Paul, according to Dr. Smart, makes no impression on the waters of the Mississippi, even in close proximity to these cities. The sewage of Troy, according to Dr. Chandler, is practically lost by dilution and change when the Hudson reaches Albany. Nearer home, we have the case of the Merrimack receiving the sewage of Lowell and Lawrence without being seriously affected. A very different state of affairs exists when a large amount of sewage flows into a small stream. This we find in the Blackstone River, into which is poured the sewage of Worcester.

Even after the river receives a comparatively large dilution from the waters of Lake Quinsigamond it is still highly contaminated and unfit for use.

Not only does dilution tend to prevent the harmful effects of sewage, but there is always going on a process of self-purification of rivers. The micro-organisms are here active, and promote the oxidation of the organic matter. Subsidence of the heavier solid portions of the sewage to the bottom of the stream removes also much of the actively decomposing matter from the flowing water.

It is not possible to give an answer in figures to the question when a water, once polluted by sewage, is sufficiently diluted or purified to be fit for drinking. But we may say in a general way that when it no longer undergoes change, or, in other words, when the changes consequent on the pollution are complete, then the danger is probably past. We get evidence of this completed change in the absence of free ammonia, and in the permanence of the albuminoid ammonia, if it is present.

In the light of the foregoing let us look again at the analysis of the water given at the beginning of this paper, and see what the record indicates. It is from Boston's Sudbury and Cochituate supply as it flows from the tap at the Institute of Technology. Its mineral contents are low, as shown in the fixed solids, and the water is soft. The amount of organic matter is high, as shown in the loss on ignition, in the albuminoid ammonia, and in the peaty odor on ignition. The amount of nitrogen completely oxidized into nitric acid is small, as is usually the case in surface waters. There is no nitrogen as free ammonia, and since the albuminoid ammonia is high we infer that the nitrogenous organic matter does not change readily. If we keep this water (as was actually done in this case) and examine it after a month's exposure to the air, and still find no change in the condition of the organic matter, then we have proven its stable condition. Any decomposing matter from drainage which it may have originally contained has disappeared as such from the water.

The objectionable odor often present in this water, while far from desirable in a drinking water, has no relation to animal decay. It is doubtless the odor inherent in certain low vegetable organisms suspended in the water, and has, in all probability, no sanitary signi-

ficance. The actual amount of material in the water which gives rise to this odor is extremely minute.

The pollution of ground waters is ordinarily a very much simpler problem for investigation. The filtration of waters through porous soils, if not too rapid, results, through the action of micro-organisms, in the complete mineralizing of the organic matter, — the conversion of the carbon into carbonic acid, the hydrogen into water, and the nitrogen into nitric acid. A ground water should, therefore, be quite colorless, and practically free from ammonia in any form. If the water has never contained any considerable amount of vegetable or animal nitrogenous matter, it will be low in nitrates; if, on the other hand, it was formerly polluted with animal matter, we must expect it to be high in nitrates. If we find in a ground water both nitrates and ammonia, the inference should be drawn that the purification from organic matter is incomplete. The presence of even a very small amount of organic matter in a well water is a matter for grave suspicion and anxiety. The usual source of contamination of a well is a cesspool near by, or the refuse thrown on the ground near a house, or the drainage from a stable or barn. The purifying power of a porous soil to convert this decaying matter into harmless mineral matter is very great, but it may be overtaxed. Suppose the well is lower than the house or barn, the soluble refuse matters then drain towards the well. It may happen in the course of time that excessive drainage will cause the upper layers of the soil to become sewage-soaked, and that the effective thickness of soil for purification will gradually become less and less until it is insufficient, and the well water which has been hitherto good becomes bad. Again, an unusually heavy or long-continued rain may wash the drainage matters through the soil so rapidly that there is not time enough to effect a complete purification before the water reaches the well. An impure well water is usually more to be feared than an impure pond water on account of the nearness of its sources of pollution.

To sum up in a word the lessons which the chemical examination of water teaches us: it is only by constant watchfulness over its condition, and of its possible sources of contamination, that we can feel sure of the fitness of a water for drinking.

JOHNSON HEAT-REGULATING SYSTEM.

At the close of Prof. Drown's paper the chairman introduced Mr. Wm. F. Chester, who exhibited and described "The Johnson Heat-Regulating System."

Mr. CHESTER said: In describing the details we will divide the apparatus into two departments, viz.: 1st, the electrical or controlling portion. 2nd, the pneumatic or working portion.

The electric circuit comprises the thermostat, the battery, and portions of the electro-pneumatic valve.

The thermostat used is composed of strips of brass and hard rubber riveted together. The hard rubber being about eight times as sensitive to changes of temperature as brass, it cannot expand or contract uniformly, being restrained on one side by the brass. The result is that the thermostat or compound strip will bend to the right or left, forming an arc or bow, as the temperature rises or falls. Attached to the end of the strip is a light tongue of metal provided with platinum contact points on either side. As the end of the compound strip bends to the right or left in response to the changes of temperature, the attached metallic tongue will touch one or another of two contact points provided for it and complete an electric circuit, which, by means of the battery, will operate the electro-pneumatic valve, the latter setting in motion the power which operates the heat supplies. The thermostat is provided with a scaled adjustment by which the temperature can be varied. For instance, in a dwelling it is generally desired to keep the temperature lower at night than during the day.

The battery is generally from two to four Leclanche cells, a slight impulse from which being sufficient to control the power to start or stop a Corliss engine.

The electro-pneumatic valve is composed first of two magnets, one to attract the armature in one direction, and the other to draw it back again. The armature is pivoted at the center, with the magnet poles at the swinging ends; it is placed in an air-tight chamber, and performs two functions in response to each impulse of electricity, namely, it first breaks the electrical circuit on one side as soon as it moves, and completes it on the other ready for the thermostat to throw it in the opposite direction, allowing the battery to be closed only for the

shortest amount of time required to move the armature. The second function is to control the supply of compressed air which flows through the air-tight chamber referred to.

The pneumatic portion includes the air pump, the tank in which is stored the air under pressure of ten pounds, the air-tight chamber of the electro-pneumatic valve, the various diaphragm valves at the heat supplies, and the piping which connects the parts just enumerated.

The pneumatic chamber of the electro-pneumatic valve has three openings, all controlled by the magnet armature within the chamber. The first leads to the air supply or tank, the second to the diaphragm valves at the heat supplies, and the third is an escape for the air when the pressure is removed at the diaphragms.

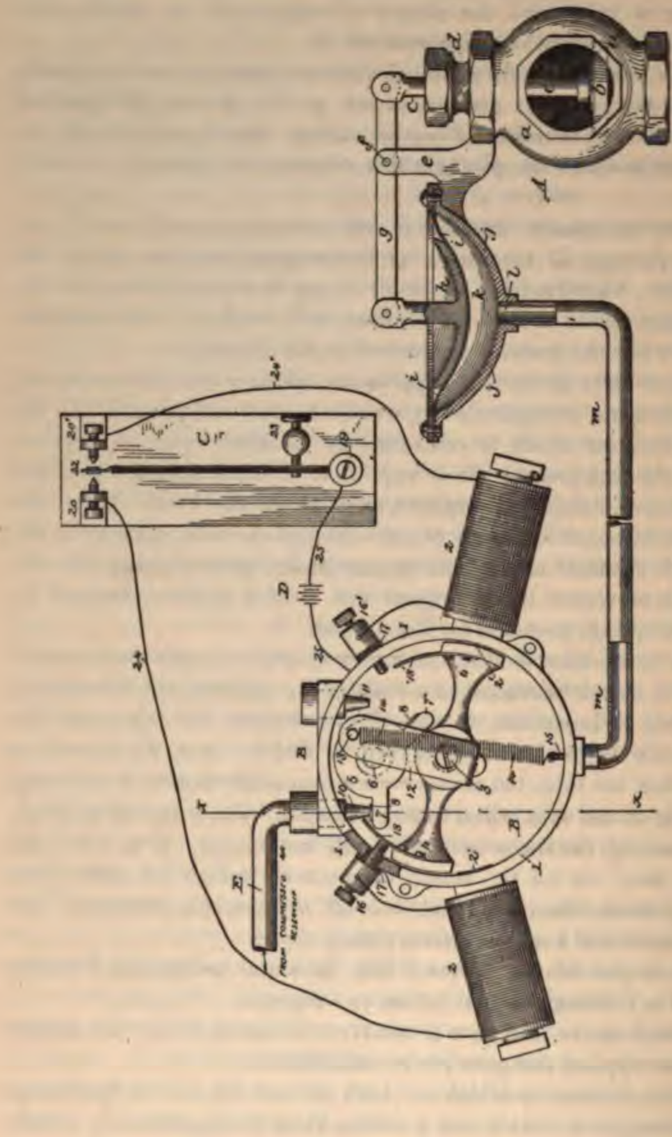
The valves at the heat supplies are operated by rubber or metallic diaphragms, strengthened by wooden saucers and propelled by the compressed air which is controlled by the electro-pneumatic valve. When the compressed air is applied to a diaphragm, it closes the steam valve, damper or register, shutting off the heat. When the pressure is removed, the air escapes through the third opening in the air-tight chamber of the electro-pneumatic valve, allowing the diaphragm to return to its original and normal position, assisted by metallic springs provided for the purpose.

In case steam is used, three very desirable results are attained: 1st, both valves connected to a radiator are operated simultaneously, rendering it impossible to cut off one without the other, and the valves are left either fully opened or closed. 2nd, the stem of a valve does not turn, but moves with a piston-like motion, thus saving grinding at the seat, which occurs when the valve is turned by hand. The packing, for the same reason, will last longer. 3rd, when the valves have cut off the supply of steam no leakage can take place through them, when the metal cools off, because the pressure of the diaphragms will keep the valves tightly closed.

It is possible by means of this apparatus to keep the temperature of a building constant within two degrees.

The lecturer then gave a number of instances where this system had been applied and gave perfect satisfaction.

The illustration which we here present shows the thermostat electro-magnetic device and a steam value in operation so plainly



JOHNSON'S SYSTEM OF HEAT REGULATION.

that no detailed description is necessary. *A* is the valve to be operated upon; *C* is the thermostat which makes at a remote point the electrical circuit which operates the electrically actuated secondary valve *B*, controlling the air under pressure operating on the valve *A*. The battery employed is represented at *D*. A pipe *E* leads from some convenient source of compressed air which is controlled by the valve *B* in such a manner that it will operate the valve *A*.

A large working model showing the manner of application to the different systems of heating was on exhibition, which was examined with considerable interest after the meeting was adjourned.

MEETING 374.

The Causes of the Recent Floods in Germany.

BY PROF. WM. H. NILES.

The Development of Bridge Building.

BY PROF. GEORGE F. SWAIN.

The 374th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 12th, at 8 P. M., Mr. H. M. Howe in the chair.

After the reading of the minutes of the previous meeting, the election of new members, and the transaction of some other business, the chairman introduced Prof. Wm. H. Niles, of the Institute, who spoke on "The Causes of the Recent Floods in Germany."

Prof. NILES first called attention to the fact that destructive floods had recently occurred in different portions of Europe. Severe storms and large accumulations of snow were to be recognized as primary causes of the inundations which had rendered the season a

memorable one in Europe. According to the incomplete accounts received, the destruction in Northern Germany had been especially marked. The sluggish flow of the rivers, the many channels which some of them occupy in parts of their courses, and the exposed condition of the adjacent low-lying lands were considered as occasions, among others, of the frequent floods of the region. But a very significant cause was to be found in the prevailing northward course of the rivers. In consequence of this the snow upon the mountains about the headwaters often melts rapidly while the ice near the mouths of the rivers has not begun to yield, and may even continue to form. Hence the spring freshets of the southern highlands discharge both water and floating ice upon the frozen rivers of the northern lowland plains. There the still firm ice upon the rivers obstructs the progress of the floating ice, thereby forming dams which cause the waters to accumulate and overflow or break through the river embankments and inundate the surrounding territory.

The speaker contrasted the fortunate southward flow of the New England rivers with the disastrous northward course of the German streams. He further remarked upon the effect of forests around the upper tributaries of southward-flowing rivers in retaining a considerable amount of snow until late in the spring, thus furnishing a protection from floods and contributing to the value of such streams for water power and for navigation.

THE DEVELOPMENT OF BRIDGE BUILDING.

The Chairman then introduced Prof. George F. Swain, of the Institute, who gave a brief sketch of the development of bridge building. The paper was accompanied by a large number of lantern views of ancient and modern bridges, complete or in process of construction, illustrating the different points mentioned.

Prof. SWAIN said: Notwithstanding that all of us are interested in the subject of bridges, popular ideas in regard to them are very vague. I am often asked, for instance, "which is the stronger, an arch or a suspension bridge?" or whether "a cantilever is a strong kind of bridge." Questions like these show that the general public do not appreciate or understand the methods followed by engineers in designing such structures. In designing a bridge, the loads to be carried are first determined. The bridge is then built so that

it shall require a load five or six times as great as the actual load to break it down, or, as we say, with a factor of safety of five or six. It will at once be asked how we can possibly have bridge disasters if bridges are built to carry five or six times the loads actually put upon them. It might seem to show engineering science to be lamentably insufficient, but the fact is that it is extremely rare for a bridge to break down from faults of construction, and when one does, it is always from extreme faults of design or material which could easily have been avoided.

I shall endeavor tonight to present to you a very brief and necessarily incomplete account of the development of bridge building, which may render clear some points often misunderstood; and at the close I shall show you some illustrations of faults of design which will show the necessity of allowing this margin or factor of safety.

The first bridges of which we have any account were of stone, and these were built long before Christ, by the Egyptians, Assyrians, and Romans. They were for the most part arches, usually semicircular, or nearly so; and by the Romans the construction of stone bridges was brought to a high degree of perfection. At that time stone arches were used on a large scale principally in connection with works of water supply, although highway bridges were also built; and there was in Rome a bridge across the Tiber, with a span of eighty-four feet, and others of smaller dimensions. Rome was supplied with water through nine aqueducts, the first two of which were built under ground, so that, in case of invasion, the city should not be deprived of water. The third, however, was built partly above ground, and so strong that the two succeeding ones were built directly above it, so that they had in places three tiers of arches, one above the other, each carrying a conduit. Arches with more than one tier were also built where but one conduit was to be carried. For instance, the Pont du Gard, which carried across the river Gardon the aqueduct supplying the city of Nismes, had three tiers of arches, and this construction was probably adopted on account of the ease with which the conduit could be maintained and inspected. This bridge, built in the time of the Emperor Augustus, was 885 feet long on top, and 157 feet above the stream. The longest arch in the lower tier had a span of 80 feet 5 inches, while others had spans of 63 and 51 feet. The arches of the upper tier had all the same span, 15 feet 9 inches.

From the time of the Romans until the Middle Ages little was done in bridge building, although the Goths, in Spain and Italy, built some stone arches, among them the remarkable aqueduct of Spoleto, with piers of over 100 meters high. In 1454 a segmental stone arch was built in France, with a span of 179 feet; and in 1599 a very bold arch was constructed in Nuremberg, with a span of 96 feet, and a rise of only 13 feet.

With the introduction of railways bridge building received an enormous impetus, and stone bridges, as well as other bridges, were constructed in great numbers in various parts of Europe. They were sometimes built with tiers of arches, one above another, but the spans nowhere exceeded about 200 feet. For works of water supply, as well, a number of large works of this kind were executed. One of the largest of these bridges is the Roquefavour Aqueduct, carrying the conduit which supplies the city of Marseilles with water. This structure is 1287 feet long, 262 feet high, and has three tiers of arches. Between 700 and 800 workmen were employed upon it for seven years, and the total cost was $750,000.

Although many bridges of similar character, for aqueducts and railways, may be found in France and Germany, there are in America comparatively few stone arches, and on railways they are rarely found, except for very short spans. The Thomas Viaduct on the Baltimore and Potomac Railroad. crossing the Patapsco River, on a curve, with eight elliptical arches of 58 feet span, was one of the earliest stone bridges in this country. Another was the Starucca Viaduct, on the Erie Railroad, 110 feet high, with 18 arches of 50 feet span; and a third crosses the Schuylkill River just above Philadelphia.

In connection with works of water supply, however, stone arches are not unfrequently met with in this country. The largest of these, and the largest existing stone arch, is the Cabin John Bridge, carrying the Washington Aqueduct, built in 1866, with a single span of 220 feet, and a rise of 57½ feet. As other and familiar examples may be mentioned the Harlem Bridge of the old Croton Aqueduct, 100 feet above the Harlem River, with seven spans of 50 feet and eight of 80 feet; and the Charles River Bridge of the Sudbury Aqueduct, which supplies the city of Boston, the principal arch of which has a span of 127 feet with 42 feet rise.

Stone arches, while expensive in first cost, have the great advantage of permanence. Many of the old Roman arches are standing today, and in good condition. A stone arch requires but little expense of maintenance, and is not liable to be outgrown as the weight of rolling stock increases, for the reason that the principle upon which the stone arch is built is essentially different from that governing the design of any other kind of structure. Other bridges are designed so as to be *strong* enough to carry given loads. If these loads are exceeded, the margin of safety is reduced. The question of stability has scarcely to be considered. A stone arch, on the contrary, is designed primarily so as to be *stable*, so that it will not tumble down, as an arch built of loose blocks may do. The question of strength must, of course, be considered; but, fortunately, if a stone arch is stable, it is almost always amply strong even for much larger loads than are generally to be put upon it. A stone arch, therefore, if once correctly designed so as to be stable, is not generally liable to be rendered dangerous even if the weight of rolling stock is doubled.

Wooden bridges first came into very extensive use on the railroads of this country; and, in fact, they have been used here more than anywhere else. One of the earliest types was the Town Lattice, patented in 1820, and built entirely of plank, joined together with oak treenails. Another early type was the Howe Truss, patented in 1840. This was the first truss in which iron and wood were combined, and it and the Town Lattice are still the standard wooden bridges. Among the early wooden bridges may be mentioned the Portage Viaduct, on the Erie Railroad, a wooden trestle bridge, about 230 feet high, which was entirely destroyed by fire, May 6, 1875. Another was the Cascade Bridge on the Erie Railroad, an arch with a span of 275 feet and a rise of 45 feet, probably the largest wooden arch ever built.

Wooden bridges may easily be made amply strong up to spans of 150 or 200 feet, and they have some advantages; but their first cost, for large spans, is not sufficiently less than that of an iron bridge, to make up for their shorter life, greater cost of maintenance, and the added danger from fire.

The earliest iron bridges were of cast iron. The first of these was commenced in 1755, in Lyons, and was intended to be three arches, each with a span of 25 meters. It was, however, not completed, the

construction being changed to wooden girders; and it was left for England, the birthplace of the iron industry, to produce the first iron bridge. This was a cast-iron arch, built between 1773 and 1779, across the River Severn, at Colebrookdale, with one span of 100 feet. It consisted of three concentric arches, connected by radial pieces, the inner arch being cast in but two parts, which were joined at the crown. The difficulty of making such large castings induced an Englishman named Payne to experiment with small hollow castings, in the shape of arch stones; and between 1793 and 1796 a cast-iron arch, with one span of 236 feet, and a rise of 34 feet, was built by Burdon over the Wear, at Sunderland, on this principle. It was composed of ribs, each built of cast-iron voussoirs put together just as the voussoirs of a stone arch are put together, and held in place laterally by three wrought-iron rods on each side of the rib or arch ring. Several bridges were built on this same system, one of which, over the Thames at Stains, collapsed; and in 1801 the noted engineer, Telford, projected a cast-iron arch to cross the Thames, at London, to be built on this system, with the extraordinary span of 600 feet.

The next step was to construct cast-iron arches as a series of larger castings, united by flanges and bolts, an example of which is the Southwark Bridge over the Thames at London, built by Rennie, between 1814 and 1819, with three spans, the longest of 240 feet, with a rise of 24 feet. Cast-iron arches were also built in France and Germany on each of the two systems described. Sometimes the castings were in the shape of tubes, and were united by flanges and bolts.* As another example of the reliance placed upon cast iron as a material for bridges, in those early days, it may be mentioned that the first plan made by Stephenson, in 1844, for the Britannia Bridge, was for a cast-iron arch, to be composed of pieces bolted together, the span to be 475 feet.

Cast iron, besides being used in arches, was also used in the shape of beams of short span; and it was furthermore common, for many years, to employ it in combination with wrought iron in the same bridge. Some of the early plate girders, for instance, were built with two webs, the top flange being of cast iron, to which the webs were bolted, while the lower flange was, of course, made of

* It may be mentioned here that an arch of this kind exists in Washington, being composed of water pipes, through which the water flows to the city.

wrought iron. But gradually wrought iron supplanted cast iron as a material for bridges, until, at the present day, the latter is not used at all, or only for unimportant parts, such as bed plates.

The first wrought-iron bridges were suspension bridges, of which a large number were built in Europe and America during the early years of this century. Then followed the use of simple beams or of rails rivetted together, spanning short openings, and gradually the modern truss bridge was developed, composed of separate bars united at their ends. In truss bridges it was for a long time very common to make simply the tension members of wrought iron, the compression members being either of wood (a method extensively used in America at one time) or of cast iron; and it is only within a comparatively few years that such so-called combination bridges have gone out of use, it being found better and more economical to make the entire bridge of one material,— wrought iron. Among the records of the patent offices, both in Europe and America, may be found innumerable examples of combination bridges, some of amazing complexity, and each possessing, in the opinion of its inventor, some virtue rendering it superior to all its competitors. An examination of these records will suffice to convince anybody that the progress in bridge building has been in the direction of simplicity; and one can only marvel that the mind of man could have conceived systems of framework and combinations of shapes and of material so intricate and so completely *incalculable*. As just stated, the early wrought-iron bridges, aside from suspension bridges, were simple beams, and from these grew the type of the plate girder, consisting of a vertical web or plate, stiffened at intervals by vertical pieces and with flanges at top and bottom. These plate girders were built of considerable size, especially in England, where engineers seemed loth to adopt the use of the framed truss. The Britannia Bridge is a striking example of the use of a plate girder under circumstances where it involved a very large waste of material. The bridge, completed in 1850, consists of two spans of 460 feet each, and two of 230 feet each. It is what is known as a tubular bridge, but is, in reality, nothing in principle but a huge plate girder, the two plate girders, one on each side of the roadway, being united at the top and bottom by one continuous flange, forming a closed tube. The waste of material alluded to arises largely from the fact that if the sides were simply thin plates

of metal they would be deformed and buckled under the action of the load; and in order to make them preserve their shape a large amount of material must be added in the form of vertical pieces, whose sole object is to stiffen this plate web. So far as carrying the load is concerned, this is literally wasted.

There are three other tubular bridges, — the Conway Bridge, with a span of 140 feet; the Victoria Bridge, across the St. Lawrence, at Montreal, with 25 spans of 242 feet, and a bridge over the Aire, at Brotherton, with a span of 225 feet. As an example of a peculiar type of bridge may be mentioned the Chepstow Bridge, across the river Wye, built in 1850–52, with a span of 300 feet. It is a truss bridge, and consists of curved upper and lower chords, with vertical and diagonal bracing between. So far, there is nothing remarkable about it; but instead of there being two separate trusses, one on each side of the roadway, each with two separate chords, there is but one upper chord, in the shape of a tube, nine feet in diameter, extending clear across the roadway, from which, on each side, run the vertical and diagonal braces. Another bridge, similar in character, is that across the Tamar, at Saltash, with three spans of 455 feet each, the upper chord, in this case, being composed of an oval tube 12 feet high and 17 feet across.

At the present day truss bridges of iron or steel are the ones in the most common use for large spans; while for short spans the plate girder is very common. Some differences may be mentioned, however, between the ordinary practice in America, as compared with that abroad. The progress in bridge building, as already remarked, has been from complexity to simplicity. American engineers prefer to build bridges in which the forces can be accurately followed through the structure, and they have discarded the use of truss bridges which consist of two chords united by a maze of net-work, like the bridge over the Rhine, at Cologne, or that over the Vistula, at Dirschau. Bridges of this kind form the transition between the plate girder, which has a solid web plate uniting the top and bottom chords, and the modern truss bridge, which has, instead, only a spider-like web, composed of single bars. Nevertheless, these net-work or lattice bridges, as they are called, are still in great favor abroad, especially in France, where the progress in bridge building has been very slow.

Another distinctive feature of American bridges is the use of the so-called trestle work. In France and Germany, when a deep and wide ravine has to be crossed, it is customary to use long spans resting on isolated piers. American engineers, however, prefer a trestle in which the spans are short and the piers light and close together. In considering the different types of bridges it is important to remember that ease of erection is a very important point to consider. European viaducts, consisting of long spans on isolated piers, have frequently been erected without the use of false works, by building the entire structure, several spans in all, complete, and rolling it out over the piers. The American system of trestle works may be erected with even greater ease, each span being built out from the preceding one, and the pier built up to it, with the aid of an overhanging traveler or crane. As a striking example of the modern American trestle, and as illustrating the rapidity with which such bridges may be constructed, the Kinzua Viaduct may be mentioned, in northwestern Pennsylvania. This bridge, 301 feet high, and 2053 feet long, was erected by 125 men within the space of four months.

A short description may now be given of some of the large bridges of recent years. Among arches, that at St. Louis, across the Mississippi River, is one of the most remarkable, and it was the first large arch of iron (steel) built in this country. It was completed in 1873, and carries a railroad below and a highway above, with three spans, the longest of 520 feet. Each span of this arch is composed of five parallel ribs, and each rib is built of two parallel tubes, 12 feet apart, 18 inches in outside diameter. These tubes are of crucible steel, in lengths of 12 feet, and connected by a system of webbing. The ends of the arch abut firmly against the masonry of the piers and abutments. Considerable difficulty was experienced in the erection of this structure. Of course, the use of false works or scaffolding in the river was out of the question, and some method had to be adopted by which the bridge could be built out from the piers and abutments. Wooden towers were erected on these piers and abutments, and, by means of cables running from these towers, each rib was built out simultaneously, piece by piece, from each end, until they met in the center of the span; but when they did meet it was found that they did not come together exactly, and that the center piece did not fit. The cables by which the arch was supported were adjusted in all

possible ways, but it was impossible to make the adjustment exact. Warm weather came on, and made matters worse by expanding the metal. The time of completion was limited, and the engineer in charge, Col. Flad, resorted to the expedient of cooling the tubes by means of ice. Many tons of ice were carried on the bridge, and packed around the tubes. Finally, after much delay, the center piece was inserted and the arch completed.

Another large arch was built very soon after that at St. Louis. It crosses the Douro River, in Portugal, with one span of 525 feet, and was built in 1875–6. It carries a railway at an elevation of 164 feet above the water. This bridge was erected in a manner similar to that used at St. Louis, but it differs from the St. Louis arch in that it rests on hinges at each abutment, so that the center piece could be inserted and fitted with comparative ease. Another arch, the largest in the world, has lately been erected very near the one just described, and across the same stream. Its span is 566 feet, and it carries a roadway at an elevation of 172 feet above the water.

Arches of iron or steel are not very frequently built except for large spans, and for these it is now generally acknowledged that an arch like that at St. Louis, firmly anchored to the abutments, is not the best type. To allow a change of shape according to the temperature, and to avoid the strains which would otherwise result, arches, especially if flat, should, like the Douro bridges, rest on hinges at the abutments, or, better still, have a third hinge at the crown.

Suspension bridges have been built ever since the year 1796, when the first one was built in Pennsylvania, culminating with the East River Bridge, so familiar to all of us. Suspension bridges are not suitable for varying loads, on account of the ease with which they change their shape and are thrown into vibration. They must be stiffened in some way. The East River Bridge, and many other suspension bridges, are stiffened by the use of a girder at the level of the roadway, which, by its rigidity, keeps the cable in shape; also by the use of stays running from the towers directly to the roadway. The East River Bridge has a central span of 1600 feet, and two side spans of 931 feet. It is 135 feet above high water, in the center, while the top of the piers is 272 feet above high water.

Another way of stiffening the cable of a suspension bridge is to make it form part of a truss. In fact, a suspension bridge may be

built precisely like an arch, except that it is turned upside down. As a beautiful example of a stiffened suspension bridge, the Point Bridge, across the Monongahela River, in Pittsburg, may be mentioned, with one span of 800 feet, two side spans of 145 feet, and a rise of 88 feet. This bridge was built in 1876, and is the only one of its kind in this country, so far as I am aware.

Arches are sometimes combined with suspension bridges, the object being that the outward thrust of the arch, at the abutments, shall be counterbalanced by the inward pull of the suspension cable, thus producing a simple vertical reaction. The best example of this type of bridge, which must not be confounded with the truss having upper and lower chords curved, is the bridge across the Elbe, at Hamburg, with spans of 307 feet.

Of all types of bridges for large spans cantilever bridges have of late years attracted the most attention. It is only within ten or fifteen years that these bridges have been built to any great extent, although the principle on which they are based is very old. An ordinary truss bridge is a frame supported at its two ends by vertical forces. A cantilever, on the contrary, may be supported at one end and at a point some distance from the other end; or at two points, each some distance from the ends. A cantilever, therefore, extends between two supports, and projects beyond them at one or both ends. The ordinary arrangement of a cantilever bridge of three spans is this: at each end a cantilever extends from the abutment out over the first pier into the central span; on the ends of these cantilevers a simple girder rests, just as it would upon piers. Of course the weight on this simple girder and on the projecting arms of the cantilever tends to tip the latter, and the abutment ends require, in many cases, to be anchored by long bolts running down into the masonry. Another arrangement of a cantilever bridge, for three spans, is to have one cantilever spanning the central opening, and projecting at each end beyond the piers into the side openings. There is, in this case, a simple girder at each end, resting on the abutment and on the projecting arm of the cantilever. In this case, therefore, there is one cantilever and two simple spans, while in the previous case there were two cantilevers and one simple span. While cantilever bridges are generally built for three spans, the same principle may be easily extended to any number of spans, as at the great bridge now being built across the Hudson, at Poughkeepsie.

As already stated, the principle of the cantilever is very old. We see it illustrated in ancient temples, where a series of openings are spanned by corbelling out on each side from the piers until a single stone will reach across. In Thibet there is a bridge of 112 feet span, built over 220 years ago, and involving the same principle; and on the line of the Canadian Pacific Railroad a bridge built by Indians was found which was precisely the same in principle as the modern cantilever. Forked branches had been set up on each side of the stream, and trunks of trees stretched out, resting in these forks, and weighted at the shore ends, and between the ends of these projecting timbers a short span was hung, and a foot-way thus carried across from bank to bank.

The introduction of cantilever bridges on a large scale was due to the German engineer, Gerber, who, in 1872, constructed a cantilever bridge of five spans across the Danube, at Vilsofen. Not many years later, in 1876, an American engineer, C. Shaler Smith, built a cantilever across the Kentucky River, on the line of the Cincinnati Southern Railroad, which was the first large railroad cantilever ever constructed. The rail was 275 feet above low water, the iron work of the pier being 174 feet in height, and the masonry 66 feet. The total length of the bridge was 1125 feet, in three spans of 375 each, and the arrangement is with one cantilever projecting 75 feet at each end into the side spans. A suspension bridge had, a number of years before, been proposed for this place by the elder Roebling, and the anchorages had already been built. The cantilever was erected without scaffolding, but with the aid of two temporary timber piers, one in each side span. The ends of the bridge were anchored to the existing anchorages, and the bridge was then built out, piece by piece, over the temporary timber pier, until it reached the main iron pier, and still farther into the central span until the two parts came together at the center. The continuity was then broken in the side spans, 75 feet from the piers, and the simple girders at each end were thus made independent of the central cantilever.

It has already been remarked that ease of erection, in the case of bridges of large span, is a very important matter, and frequently determines the type to be adopted. Ordinary bridges of short spans are erected on temporary timber staging or false works, built up for the purpose. But where a bridge crosses a deep valley or a large

and deep river, the erection of false works is frequently impracticable, and some means has to be adopted by which the bridge may be built out, piece by piece, over the openings, without intermediate support. We have seen how arches, such as those at St. Louis and at Oporto, have been built out from the piers, and how European bridges are sometimes rolled out over the piers. Now the cantilever permits, as is easily seen, of being built out, piece by piece, as soon as one span is erected. Frequently, in cantilever bridges of three spans, the side spans are built on false works, and then the center span built out from each end; or, in the case of long cantilevers, like that at Poughkeepsie, one or more of the central spans may be erected on false works, and the adjacent spans then built out. In the Kentucky River Bridge, as already stated, the existence of heavy anchorages rendered it only necessary to have the two temporary timber piers.

Since the date of the Kentucky River Bridge not fewer than six cantilevers have been built in this country, and the following may be specially mentioned: the Minnehaha Bridge, across the Mississippi, near St. Paul, is not a pure cantilever bridge. It consists of two cantilevers, united at the center of the middle span, with no simple girder between them. The Frazer River Bridge, on the Canadian Pacific Railroad, is a good example of a cantilever, and was soon followed by the great bridge across the Niagara River, just below the Falls. This bridge has a total length of about 910 feet, a central span of 470 feet, and the rail is 239 feet above the water. It was built in the remarkably short time of about eight months. The bridge over the St. John, at St. John, New Brunswick, built in 1884, has three spans, the central one of 447 feet. It has two cantilevers and a simple span in the middle, and was the first through cantilever bridge in America. At Lachine, in Canada, a so-called cantilever was built about a year ago, across the St. Lawrence River; but this is not really a cantilever bridge. The Kentucky and Indiana Bridge across the Ohio, at Louisville, is another fine example of a cantilever bridge; and the great Poughkeepsie Bridge, now in process of erection, with a total length of about 3100 feet, in seven spans, the largest 548 feet in length, will be the finest example in America of this class of structure.

In Europe cantilever bridges have also been built frequently within the past ten years, there being at present four or five in Germany.

By far the most remarkable bridge ever attempted, however, is the great Forth Bridge, now under construction in Scotland. The total length of this structure is a mile and a half, of which half a mile is made up of simple girders, forming the approaches, and about one mile is composed of a cantilever bridge consisting of two main spans of 1700 feet each, and two side spans of 675 feet each. The following brief statements will give some idea of the magnitude of this work, regarding which the engineering papers have given full details from time to time, within the past few years. The clear head-room is 152 feet above high water, the highest point 360 feet above high water. From the base of the deepest pier to the highest point is 450 feet, and the main columns at the piers are 343 feet long. The works cover 50 acres, and 3600 men are employed. The compression members are made of tubes varying in diameter from 3 to 12 feet, and made up of bent plates rivetted together. The total length of tubes will be six miles.

In closing, a word may be said in regard to the testing of a bridge, as is customary, by running a loaded train across it. Such a test is a good thing to satisfy the public mind. It shows that the bridge has borne such a load, and the probability is that it would bear it again. Nevertheless, such a test is practically of no value, and does not in the least insure the safety of a structure. A bar of iron may be broken by a much smaller load repeated a number of times than would be necessary to break the bar at once; and although a bridge may sustain a certain load once or twice or a thousand times, it may nevertheless fail upon the very next application. The only way of insuring the safety of bridges is to have them designed by men who, by experience and study, are competent for that purpose, and to take every precaution that the material used shall be of good quality. It is fortunate, however, notwithstanding the fact that faults in design are exceedingly common, and some of them very bad, that, on account of the large margin of safety allowed, bridges do, in reality, seldom actually break down. They may be knocked down by trains off the track, or a defective floor may let a train through and cause the bridge to fall; but it is rare for a bridge to collapse by the actual breaking of any of its parts under ordinary circumstances.

MEETING 375.

*Precious Stones in the Last Decade.**

BY MR. GEORGE F. KUNZ.

The 375th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 26th, at 8 P.M., President Walker in the chair.

After the reading of the records of the previous meeting, the election of new members, and the transaction of some other business, the President introduced Mr. George F. Kunz, of New York, who read a paper on "Precious Stones in the Last Decade."

Mr. KUNZ said: The American spirit of unrest finds its outlet in an incessant desire for change and novelty. In this we are sharply distinguished from the Frenchman, Englishman, or German, who believes that a good thing once is a good thing always. For us a thing must not only have excellence, but it must also be new or unique to satisfy the demands of this American trait. So, of precious stones very few fail to escape the edicts of Dame Fashion, who is influenced largely by the demands of her American followers.

During the last decade new stones have come into favor, some neglected ones have regained their popularity, and still others have been shown out entirely, such as the amethyst and cameo. The latter, no matter how finely cut, would not now find purchasers at one fifth of their former value, for about ten years ago they were eagerly sought after at from four to twenty times present prices. Rubies were considered high ten years ago, and a furthur rise was not looked for, but today they are still higher, a $9\frac{1}{4}\frac{1}{8}$ carat stone being quoted at $33,000. There is no demand at present for topaz, yet a syndicate of French capitalists has been organized to control the topaz mines of Spain, in the expectation that after twenty years of neglect this gem will again find favor in the sight of fashion. Coral has felt the change of fashion, for during the last three years

* For the fuller text and other references, see *North American Review*, July, 1888; Report of Department of Mining Statistics, 1888; *Science*, Vol. V, p. 399, Vol. VIII, p. 192, Vol. X, pp. 69, 168, 226, Vol. XI, p. 118; *Popular Science Monthly*, April, 1886, p. 824; *Amer. Asso. Advan. Science*, Vol. XXXIV, p. 250.

less than $1000 worth per annum has been imported; and in the last ten years in all $33,956 worth, whereas in the ten years preceding there was imported $388,570 worth. The popularity of amber, on the other hand, is increasing. The imports of amber beads, for the ten years, 1868 to 1878, were less than $5000 worth, whereas during the last ten years $35,897 worth have been introduced. Amber amounting to $47,000 was imported from 1868 to 1878, but over $350,000 worth from 1878 to 1888.

Ten years ago few of our jewelers carried more than the following stones in stock: diamond, ruby, sapphire, emerald, garnet, and, occasionally, a topaz or an aquamarine. The gem and mineralogical collections contained a large series of beautiful stones that were hard, of rich color, that are now known as "fancy stones," and by the French as *pierres de fantasie*. Since then considerable interest has centered in these fancy stones, and any leading jeweler is not only expected to be familiar with but to keep in stock almost all of them. This change may be partly referred to the fact that since the Centennial Exhibition art matters have received more attention among us than before.

The Duke of Connaught gave his bride a cat's-eye ring as an engagement token, and this was enough to make that stone fashionable, and to increase its value greatly. The demand soon extended to Ceylon, where the true chrysoberyl cat's-eye is found, and stimulated the search for it there. In the chrysoberyl cat's-eye the effect is the result of the twinning of the crystal, or of a deposit between its crystalline layers of other minerals in microscopic inclusions. If the stone be cut across these layers, *en cabochon*, or carbuncle-cut, as it is called, a bright line of light will be condensed on the dome-like top of the stone. In the search for these chrysoberyl cat's-eyes there have been found an endless series of chrysoberyls of deep golden, light yellow, yellow green, sage green, dark green, yellowish brown, and other tints. They are superb gems, weighing from one to one hundred carats each, ranking next to the sapphire in hardness. They gave a great surprise to the gem dealers, for it was found that the darker leaf-green or olive-green stones possessed the wonderful dichroitic property of changing to columbine red by artificial light, the green being entirely subdued and the red predominating. They were, in fact, alexandrites, a gem which had formerly been found

only in Siberia, and even there of poor quality. Though found in large crystals, a perfect gem of even one carat was a great rarity. Here, however, fine gems, rarely under four carats, were found, and an exceptional one weighing sixty-seven carats. They can be numbered among the most remarkable gems known. Strange to say, among this alexandrite variety a few have been found which combine the characteristics of the cat's-eye and the alexandrite, and were, in fact, the alexandrite cat's-eye.

Moonstones, also from this same province of Kandy, Ceylon, were brought to light by this search for cat's-eyes. It would not be an over-estimate to say that 100,000 of these stones have been mounted here in the last four years. They vary in size from one-eighth of an inch to nearly two inches long and one inch thick, and many of them surpass anything hitherto known of their kind in beauty and size. Those that display the *chatoyant* white and the hazy blue color are especially beautiful.

The demand for the cat's-eye also brought into notice the then rare mineral from Asbestus Mountain, forty miles north of the Vaal River, South Africa, known as crocidolite, more especially that variety that has been altered to a quartz cat's-eye. In this stone an infiltration of siliceous material coated each fiber with quartz or chalcedony, giving it the hardness of seven. This pleasing stone sold readily for six dollars a carat, and at the outset even more; but owing to the excessive competition of two rival dealers, who sent whole cargoes of it to the London market, the price fell to one dollar, or even to twenty-five cents, per pound by the quantity. Even table tops have been made of this material by veneering. Vases, cane heads, paper weights, seals, charms, etc., were made of it, and sold in large quantities. Burning it produced a bronze-like luster, and by dissolving out the brown oxide-of-iron coloring an almost white substance was obtained, which was dyed by allowing it to absorb red, green, and brown-colored solutions. These, owing to the delicacy of the fibers, were evenly absorbed.

Ten years ago this material was practically unknown; but so extensively has it been sold that, today, it is to be found on every tourists' stand, whether on the Rigi, on Pike's Peak, in Florida, at Los Angeles, or at Nijni Novgorod, showing how thoroughly organized is the system of distribution in the gem market. Missionaries have never spread a religion half so rapidly as traders have disseminated the cat's-eye.

The green quartz cat's-eye from Hoff, Bavaria, has also been brought into use and quite extensively sold, but at present both these varieties are only used in the very cheapest jewelry.

Since it has become generally known that Queen Victoria is partial to the opal, the old and stubborn superstition concerning it, which is said to date from Scott's Anne of Gierstein, has been slowly yielding, until now the gem has its share of popular favor. During the last two years ten times as many opals have been imported as were brought here during the preceding decade, many of these being the fine Hungarian stone. Mexican fire-opals are much more common, as those tourists know to their sorrow who buy these stones at exorbitant prices, in Mexico, hoping thus to pay the expenses of the trip, only to find, on reaching New York, that they are worth only about a quarter of what they paid for them.

The opal mines of Mexico are situated on the Hacienda Esperenza, near Querretera. It is believed that a demand for 50,000 stones, per annum, could be supplied without raising the price perceptibly, since in the market of precious stones the demand generally raises the price. The opal mines of Dubreck, Hungary, yield the government a revenue of $6,000 annually; and their output is so carefully regulated that the market is never glutted.

About ten years ago a new and very interesting variety of opal was brought from the Baricoo River, Queensland, Australia, where it was found in a highly-ferruginous jasper-like matrix, sometimes apparently as a nodule, and then again in brilliant colored patches, or in specks affording a sharp contrast with the reddish-brown matrix, which admits of a high polish and breaks with a conchoidal fracture. Many of these stones are exceedingly brilliant. They are of the variety known as harlequin opals, their color being somewhat yellow as compared with the Hungarian stone, although not less brilliant. The rich ultramine-blue opal is quite peculiar to this locality. A company, capitalized at $200,000, has been formed, and the gems are extensively mined. Many curious little cameo-like objects, such as faces, dogs' heads, and the like, are made by cutting the matrix and the opal together.

Green beryls, blue and green sapphires, white and bluish topaz, and garnets and zircons, have been found at New England, New South Wales; and from the Abercrombie River come precious opals.

Never have pearls been more popular or commanded such high prices as during the past ten years. At present nothing is considered in better taste than the pearl, on account of its purity and subdued beauty. This unusual demand has had the effect of greatly stimulating the search for them, especially on the west coast of Australia, the Thursday Island, the Sooloo Archipelago, in Ceylon and the Persian Gulf, and also along the coast of Lower California.

The demand embraced pearls of all colors except the inferior yellow. The fine black pearls from Lower California have been in great request, single ones bringing as much as $8000. With these black pearls are found many beautiful gray and grayish-brown pearls. The different fisheries of the world produce fully $1,000,000 annually, of which our California fisheries produce probably one sixth. Kentucky, Tennessee, and Texas have given us over $10,000 worth of pearls per annum. Their remarkable fresh-water pearls, especially the pink ones, are unrivaled for delicacy of tint. But within the last five years many of the fancy-colored pearls have received their variety of color not from nature but from artificial means.

In 1882 a very remarkable discovery of sapphire was made in the Zenskar range of the northwestern Kashmur Himalaya, near the line of perpetual snow, a short distance from the village of Machel, and one-half day's journey from the top of Umasi Pass. The stones were found at the foot of a precipice, where a land slide had taken place, the including rock being gneiss and mica.

At first they were collected by the villagers, who were attracted merely by the beautiful colors; and so little was their value realized that they were used as flints for striking lights with steel. So abundant were they at first that one writer speaks of having seen about a hundred weight of them in the possession of a single native. Several crystals were found weighing from one hundred to five hundred carats each.

[The lecturer next spoke of the Burmese ruby mines, then of the diamond mines of India, Borneo, Australia, and South Africa, giving a detailed account, illustrated by different lantern views, of the ancient and modern methods of working the diamond mines. He stated that the yield of the mines of India, Borneo, and Australia was not over one per cent, and that of the Brazilian mines was only about nine per cent, of the total yield. The yield of the South Afri-

can mines has been very great during the last ten years. 27,868,587 carats, in the rough, valued at £31,427,339, have been mined. The average size of these diamonds has been much larger than from any of the old mines.]

During the last few years it has been suggested by E. J. Dunn, E. Cohen, Mr. Huddleston, and Prof. Rupert Jones that the South African diamonds were formed in a sort of volcanic mud. Mr. Huddleston thought that the action was hydrothermal rather than igneous, the diamonds being the result of the contact of steam and magnesian mud under pressure upon the carbonaceous shales. He compared the rock to a boiled plum pudding.

At the meeting of the Manchester Literary and Philosophic Society, held October 21st, 1884, Prof. H. E. Roscoe presented a paper on the diamond-bearing rocks of South Africa, in which he said that he had noticed that a peculiar smell, somewhat like that of camphor, was evolved on treating the soft blue diamond earth with hot water. He powdered and digested a quantity of this earth with ether, and, on filtering and allowing the ether to evaporate, he obtained a small quantity of a crystalline, strongly-aromatic body, volatile, burning easily with a smoky flame, and melting at about 50° Cent. Unfortunately, the quantity obtained was too small to admit of a full investigation of its composition and properties. He suggested that perhaps the diamond was formed from a hydrocarbon simultaneously with this aromatic body.

Prof. H. Carvill Lewis, at the British Association meeting, September, 1886, read a paper on the genesis of the diamond, in which he stated that from the De Beers mine, at a depth of six hundred feet, there had been sent him specimens of rock which were unaltered, and proved to be a peridotite containing carbonaceous shale. He added, that from information he had received from New South Wales, Borneo, and Brazil, he believed that all diamonds were the result of the intrusion of a peridotite through carbonaceous rocks and coal seams.

The similarity of the South African peridotite to a peridotite described by Mr. J. S. Diller, in Elliot County, Ky., led Prof. Lewis to suggest interesting possibilities there, and through the invitation of Prof. Proctor, of Kentucky, Major Powell sent Mr. J. S. Diller and myself to examine this Kentucky peridotite. Although the associated

minerals were identical with the South African, the pyrope garnet, ilminite, biotite, and pyroxine among others being present, yet, by an analysis of the enclosed carbonaceous shales from which it is believed that the diamond is formed, it was found that the Kentucky shale contained only .681 of carbon, while the South African contained 35 per cent, and could be readily ignited with a match. Hence, unless the peridotite has penetrated the older and richer Devonian shales, the probability of finding diamonds there has been considerably weakened by the investigation.

A beautiful twinned hexoctahedral diamond crystal of 4½ carats was found at Dysartville, N. C., in June, 1885, and sent to me for examination. On visiting the locality I authenticated all the facts of the finding. A boy had discovered the "pretty trick," as he called it, at a spring, and it was some time before the rural folk suspected that it was a diamond. None of the associations of the diamond were observed at the spring, therefore it is probable that the stone was carried to the spring by some miner who was washing up his gold, and failed to notice the shining crystal among the "wash-up." The crystal is not pure white, having a faint grayish-green tint, although it is quite perfect as a gem, and would make, when cut, a stone worth about $100. A number of stones called diamonds have been found at Brackettstown, near by, but they have proved on examination to be transparent zircon or smoky quartz.

[Mr. Kunz here gave an account of numerous large diamonds; also of many notable collections of precious stones. He next spoke of the investigations which have been made, which leave but little doubt that microscopic diamonds have been found in meteorites.]

The handsomest and lowest-priced of our ornamental stones, and one which has been introduced most extensively, is the so-called Mexican onyx, or Tecalli, as it was first called from the town of that name in the State of Puebla, Mexico, where it is found. The deep colors are richer than those of any marble known, and its wavy, stalagmitic structure, and the high polish it admits of, have made it popular throughout the whole civilized world. With a metal mounting the effect is greatly enhanced. It occurs in almost unlimited quantities, and fully $500,000 worth has been used in the United States for marble tops, mantels, vases, etc.

The existence in Arizona of deposits of agatized and jasperized

woods, richer in color than those of any other locality thus far discovered, was known for many years, but public attention was first called to them by an exhibit of this beautiful material at the New Orleans Exposition, through the enterprise of Mr. Wm. Adams, Jr. The bulk of the deposit is situated eight miles south of Corizza, a station on the Atlantic and Pacific Railroad, twenty-four miles southeast of Holbrook. The locality of this fallen and buried forest has been appropriately named Chalcedony Park. Some of the trees were two hundred feet in length originally, and many of them are broken up into uniform sections, resembling a pile of car wheels in appearance, and varying in diameter from a few inches to as much as eight feet. The fracturing was evidently the result of weathering.

The colors present various shades of yellow, red, brown, and white, sometimes in spots, giving a mottled appearance; and again all the blending imperceptibly to produce a much more pleasing and harmonious effect than the decided banding of an agate. The original structure is in many instances preserved, but generally it has been entirely replaced by the agate or jasper. One of the wonders of this park is a silicified tree, one hundred feet in length and from three to four feet in diameter, which spans a gulch fifty-six feet in width and forty-five feet in depth, forming what is perhaps unique,— a natural bridge of agate, the gulch having been washed out under the tree after its silicification.

Although this material occurs here in immense quantities, only a portion of it is suitable for cutting. Very little attention has hitherto been paid to cutting masses of agate more than one foot in diameter, and when this material first began to be utilized for ornamental purposes the problem of how it should be cut seemed to present insurmountable difficulties. After a great deal of costly experimenting, however, the Drake Company, of St. Paul, Minn., solved the problem. They have erected cutting and polishing works at Sioux Falls, Dakota, utilizing the water-power there afforded, and have succeeded in cutting and polishing sections of the material three feet in diameter. Thus American enterprise and ingenuity accomplished what it was impossible to have done at Oberstein, where agates have been cut for over three hundred years. To illustrate the hardness of the material, it is estimated from the sawing of sections two feet in diameter that it would be possible to saw about one hundred sections

of Mexican onyx of the same size with the same power, fifty sections of marble, and ten of granite. Still, in spite of its excessive hardness, this is destined to become one of our richest American ornamental stones. It is already used for mantels, table tops, tiling, paper weights, inkstands, as well as for an endless variety of charms and other objects similar to those made from onyx.

The turquoise, long known as occurring at Los Cerillos, New Mexico, was known to the natives before the arrival of the Spaniards, who also mined them for a time. It is now cut by the natives into flat beads or other ornaments, which are sold as charms along the lines of the railroads. The mines have been worked to some extent. The color is not fine, but these green stones have been artificially stained to a fair blue, and many of them have been sold as fine turquoises. Suspecting that the color was not genuine, I tested it with ammonia, and found that it dissolved readily in a moment, whereas the color of the Persian, or even of the Egyptian turquoise, is unaffected if the stone is left in ammonia for twenty-four hours. Prof. William P. Blake describes a new locality of the turquoise at Turquoise Mountain, an outlying spur of the Dragoon Mountains, now called Turquesa, twenty miles from Tombstone, in Cochise County, Arizona. The color, he stated, is apple and pea green, exactly like that of the New Mexican stone. This deposit had evidently been worked as early as the New Mexican, since there were large piles of débris around the ancient excavations, which were probably made before the country was inhabited by the Apaches. These turquoises, like those of the New Mexican locality, have little commercial value.

Prof. F. W. Clarke and Mr. J. S. Diller, of the United States Geological Survey, have made an exhaustive study, both chemically and microscopically, of the New Mexican turquoise, as well as the trachyte in which it occurs, and found that, with the exception of the very dark-green variety, the series of analyses agreed with the analyses of the Persian turquoise and the Californian turquoise, replacing apatite or phosphate of lime, in each case the base standing to the acid very slightly in excess of two to one. This excess was accounted for upon the supposition that it is represented by a fair admixture of iron, and that possibly it all represents an alteration from apatite. It is of interest to note that V. von Zepharovitch and G. E. Moore described and analyzed a turquoise from Taylor's Ranch, Presno County, California, which here replaced crystals of apatite.

What may be of considerable use in the arts, and as an ornamental stone, is the banded jasper found in Graham County, Kansas, which is beautifully banded like an onyx in red, yellow, brown, white, and other colors. Pieces one foot long and six to eight inches thick can be taken out. As a banded jasper it is unrivaled in the whole world.

The small brilliant rutile crystals from Alexander County, N. C., have furnished perfect black gems, which approach the black diamond more closely in appearance than any other known gem.

The well-known labradorite rock in Lewis County, New York, is so plentiful that the reflection of the boulders has given the river that runs through the locality the name of Opalescent River. This is being extensively cut as an ornamental stone.

At Auburn, Me., hundreds of crystals of tourmaline have lately been found. Some of these have been cut into gems, though they do not rival those from the more famous locality at Paris, Me. In color they are generally light green, light blue, and light red.

The Mount Mica Mining Company, of which Dr. A. C. Hamlin, of Bangor, Me., is the organizer and president, began operations at the famous tourmaline locality at Mount Mica, near Paris, Me., in 1879. They prosecuted the work for three summers, and were rewarded by the discovery of some of the finest green, blue, and white tourmalines ever found. A crystal of blue tourmaline, measuring nine inches in length, and a green tourmaline ten inches long, were among the most remarkable finds, the proceeds of which, altogether, have amounted to somethlng over $5000.

A white opaque variety of hydrophane, in rounded lumps, from 5 m. to 25 mm. in diameter, with a white, chalky, or glazed coating, somewhat resembling the cacholong from Washington County, Ga., has recently been brought from Colorado. For its power of absorbing liquid it is quite remarkable. When water is allowed to drop on it slowly, it first becomes very white and chalky, and then, gradually, perfectly transparent. This property is developed so strikingly that the finder has proposed the name "Magic Stone," for the mineral, and has suggested its use in rings, lockets, charms, etc., to conceal photographs, hair, or other objects which the wearer wishes to display only when his caprice dictates. The specific gravity of several specimens, both wet and dry, was taken, and it was found that this peculiar stone absorbs more than an equal volume of water.

This stone is identical with one brought from China, several centuries ago, and described by De Boot, De Laet, Boyle, and others, as the *oculus mundi*, or world's eye, and of the *lapis mutabilis*, which, when wet, became entirely transparent, except a central nucleus (possibly a core of chalcedony) that still remained white. If the central core was black, the stone was called *oculus beli*.

In 1883 topaz was first discovered in Colorado, and since then it has been found in some abundance at Platte Mountain, Cheyenne, and at Crystal Peak, near Pike's Peak. Many of the crystals are remarkable for their size, several of them weighing over a pound each. The smaller ones are transparent, and range in color from pellucid white to rich cinnamon brown; some few are light blue and light green. The two largest weighed 125 and 198 carats respectively, and equaled those from any known locality; but $3000 would probably be a fair estimate of the value of all that have been found there.

At Stoneham, Me., while examining a series of minerals which had been collected by N. H. Perry, I identified topaz; and, after considerable blasting, many interesting minerals were found, and among them a few crystals of this mineral measuring one foot on a face. There were a number of smaller ones, some of which had small transparent spots that afforded a limited number of gems of several carats each.

Five years ago the existence of rock crystal of any size was almost unknown in the United States; but about that time a large, clear mass, weighing thirteen pounds, which had been found in Alaska, was brought to New York city and made into thin slabs for hand mirrors. In 1885 a fifty-one pound fragment, said to have been broken from a crystal which originally weighed five hundred pounds, was found in Chestnut Hill Township, Ashe County, N. C. On visiting the locality I found that most of the crystals in that locality were obtained either by digging where one crystal had been found, or by driving a plow until it unearthed them. Several dozen crystals in all have been found here, one mass of thirty pounds being almost absolutely pure. Some of them would afford larger masses of clearer rock crystal than has before been obtained at any American locality. It is of use for crystal balls, clock cases, hand mirrors, and similar objects.

In 1877 F. Pisani, of Paris, described a transparent golden-yellow spodumene, which had been found in Brazil, and was supposed to be chrysoberyl. Strange to say, at the same time a yellow-green variety, associated with emerald-tinted beryl crystals, the latter called "green bolts" by the farmers, was obtained by Mr. J. A. D. Stephenson, of Statesville, N. C., who called the attention of the northern mineralogists, Norman Spang, Dr. F. A. Genth, and W. E. Hidden, to it. The latter formed a company to mine the emeralds, and sent a specimen of this mineral, which he supposed to be diopside, a variety of hornblende, to Dr. J. Lawrence Smith, of Louisville, Ky., who found, upon analysis, that it was a transparent spodumene instead of diopside, as had been supposed, and named it hiddenite.

This locality has furnished several dozen of the finest emerald crystals that have ever been found anywhere. Among them is a crystal eight inches long, and another weighing 8¾ ounces, valued at $1000. Both of these, together with many other fine minerals found here, are in the famous Clarence S. Bement collection, Philadelphia, the finest private collection of minerals in existence. One light emerald furnished a gem of 5⅛ carats, but this, as all found up to the present time was too light in color to be of much value.

In 1883 one-half of a fine blue crystal of beryl was found on a farm one mile from Stoneham, Oxford County, Me., on a pasture. This led to some search, in which the remaining half of this, as well as a number of other crystals were found, and from one of these was cut the finest aquamarine found on this continent, weighing 125 carats, as well as other fine stones, weighing some hundreds of carats in all. Some fine transparent yellow beryls were found at Albany, Me.; at the Avondale quarries, in Delaware County, several thirty carat stones, and many smaller ones, have also been found; and at a mica mine, near Litchfield, Conn., several thousand dollars' worth of this gem have been obtained. Amelia County, Va., and several localities in North Carolina, have also afforded good specimens.

At Mount Anteros, Colorado, have been found some beautiful beryls of good blue and green colors, associated with phenakite, and further working may bring some fine gems to light.

Prof. R. B. Riggs, of the laboratory of the Geological Survey, recently made over twenty-five analyses of tourmalines of all colors. He found the question of the color of the lithia tourmaline a very

interesting one. The color of the iron and magnesian varieties depends on the amount of iron present. It ranges from the colorless De Kalb through all the shades of brown to the Pierrepont black, while the lithia tourmaline, containing more or less manganese, gives us the red, green, and blue as well as the colorless varieties. The shades of color do not depend on the absolute amount of manganese present, but rather on the ratios existing between that element and the iron. Thus when the amount of manganese and iron are equal, we have the colorless, pink, or very pale green tourmaline. An excess of manganese produces the red varieties; and if the iron is in excess, the various shades of green and blue are the result.

The subject of artificial gems is at the present moment of considerable interest, not only commercially, but also as furnishing an example of the surprises the modern science of chemistry is constantly giving us. In the spring of 1886 the syndicate of dealers in diamonds and precious stones, of Paris, were informed that certain stones, which had been put upon the market by a Geneva house and sold as rubies from a new locality, were suspected to be of artificial origin. It was surmised that they were obtained by the fusion of large numbers of small rubies, worth at the most a few dollars a carat, into one fine gem, worth from $1000 to $3000 a carat.

Some of these artificial stones were kindly procured for me by Messrs. Tiffany & Co. I was not, however, permitted to break them for analysis, to observe the cleavage, or to have them cut so that I could observe the optical axes more correctly; but I could have detected the artificial nature of these productions with a pocket lens, as their whole structure is that peculiar to fused masses. Examination elicited the following facts: the principal distinguishing characteristic between these and genuine stones is the presence in these of large numbers of spherical bubbles, rarely pear-shaped, sometimes containing stringy portions, showing how the bubbles had moved. These bubbles all have rounded ends, and present the same appearance as those seen in glass or other fused mixtures. They are nearly always in wavy groups or cloudy masses. When examined individually they always seem to be filled with gas or air, and often form part of a cloud, the rest having the waviness of a fused mixture. Some few were observed inclosing inner bubbles, apparently a double cavity, but empty. In natural rubies the cavities are always angular or

crystalline in outline, and are usually filled with some liquid; or, if they form part of a "feather," as it is called by the jewelers, they are often arranged with lines of growth. Hence the difference in appearance between the cavities in the natural gem and those in the fused gem is very distinct, and can readily be detected by means of the pocket lens. I have failed to find in any of the artificial stones even a trace of anything like a crystalline or angular cavity. Another characteristic is that in many genuine rubies we can see a flossy-looking structure (called "silk," by the jewelers), which, if examined under the microscope, or under a 4-10 to 8-10 inch objective, we find to be a series of cuniform or acicular crystals, often iridescent, and arranged parallel with the hexagonal layers of the crystal. When in sufficient number these acicular and arrow-shaped crystals produce the asteria or star effect if the gem is cut *en cabochon* (as the carbuncle or convex cut is called), with the center of the hexagonal prism on the top of the *cabochon*. I have failed to find any of them in the stones under consideration, or even any of the marking of the hexagonal crystal which can often be seen when a gem is held in a good light, and the light allowed to strike obliquely across the hexagonal prism. Dr. Isaac Lee has suggested that these acicular crystals are rutile, an oxide of titanium, and interesting facts and illustrations have been published by him. From my own observations on many specimens, I believe there is little doubt of the truth of this hypothesis. My explanation is that they were deposited from a solution, either heated or cold, while the corundum was crystallizing, and I doubt very much whether they will ever be found in any substance formed by fusion.

The hardness of these stones I found to be about the same as that of the true ruby, 8, or a little less than 9, the only difference being that the artificial stones were a trifle more brittle. The testing point used was a Siamese green sapphire, and the scratch made by it was a little broader but no deeper than on a true ruby, as is usually the case with a brittle material. After several trials I faintly scratched it with a chrysoberyl, which will also slightly mark the true ruby.

The specific gravity of these stones I found to be 3.93 and 3.95. As that of the true ruby ranges from 3.98 to 4.01, it will be seen that the difference is very slight. It is doubtless due to the presence [illegible]uded bubbles in the artificial stones, which would slightly

decrease the density. As a test, this is too delicate for jewelers' use, for if a true ruby were not entirely clean, or if a few of the bubbles that sometime settle on gems in taking the specific gravity were allowed to remain undisturbed, it would have about the same specific gravity as one of these artificial stones.

I found, on examination by the dichroscope, that the ordinary image was cardinal red, and the extraordinary image a salmon red, as in the true ruby of the same color. Under the polariscope, what I believe to be annular rings were observed. With the spectroscope the red ruby line, similar to that in the true gem, is distinguishable, although perhaps a little nearer the dark end of the spectrum.

The color of all the stones examined was good, but not one was as brilliant as a very fine ruby. The *cabochons* were all duller than those of fine, true stones, though better than poor ones. They did not differ much in color, however, and were evidently made by one exact process or at one time. Their dull appearance is evidently due in part to the bubbles. The optical properties of these stones show that they are individual, or parts of individual, crystals, and not agglomerations of crystals or groups fused by heating.

In my opinion, these artificial rubies are produced by a process somewhat similar to that described by Frémy and Feil,* by fusing an aluminate of lead in connection with silica, in a siliceous crucible, the silica uniting with the lead to form a lead glass, and liberating the alumina, which crystallizes out in the form of corundum, in hexagonal plates, with a specific gravity of 4.0 to 4.1, and the hardness and color of the natural ruby, the latter being produced by the addition of some chromium salt. By this method rubies were formed that, like the true gem, were decolorized temporarily by heating.

It is not probable that these two stones were formed by Gaudin's method,† by exposing amorphous alumina to the flame of the oxyhydrogen blow-pipe, and thus fusing it to a limpid fluid, which, when cooled, had the hardness of corundum, but only the specific gravity 3.45, much below that of these stones. Nor is it at all likely that they are produced by fusing a large number of natural rubies or corundum of small size, because by this process the specific gravity is lowered to that of Gaudin's product. The same also holds good of quartz, beryl, etc.

* *Comptes Rendus*, 1887, p. 1039. † *Comptes Rendus*, t. XIX., p. 1842.

The French syndicate referred the matter to M. Friedel, of the Ecole des Mines, Paris, supplying him with samples of the stones for examination. He reported the presence of the round and pear-shaped bubbles, and determined the hardness and specific gravity to be about the same as in the true ruby.

On the receipt of M. Friedel's report the syndicate decided that all *cabochon* or cut stones of this kind should be sold as artificial, and not as precious gems. Unless consignments are so marked the sales are considered fraudulent, and the misdemeanor is punishable under the penal code. All the sales that had been effected so far, amounting to some 600,000 or 800,000 francs, were canceled, and the money and stones were returned to their respective owners.

The action taken by the syndicate has fully settled the position which this product will hold among gem dealers, and there is little reason to fear that the true ruby will ever lose the place it has occupied for so many centuries. These stones show the triumph of modern science in chemistry, it is true; and although some may be willing to have the easily-attainable, there are those who will always desire what the true ruby is becoming today, the unattainable. One will always be nature's gem, and the other the gem made by man.

In 1880 MM. Frémy and Peil endeavored to retard the reactions in this experiment, so as to increase the size of the crystals. M. Stanislas Meunier* decomposed in a red-hot tube chloride of aluminum by the use of steam. In several experiments magnesium or zinc were also used as re-agents. Corundum was thus produced in hexagonal plates or crystalline grains. MM. Fouqué and Michael Levy accidentally observed the formation of corundum in beautiful hexagonal plates while they were fusing microline feldspar with fluorite. The corundum, by sublimation, lined the platinum cover of the crucible in which the experiment was made.

Last of all, M. F. Parmentier,† in a work relative to the action of molybdates upon oxides by dry process, has announced that the fusion of amorphous alumina with bimolybdate of potash, will furnish corundum in plates like tridymite. It is important to keep the temperature of the crucible high, for if it is lowered an opposite reaction takes place.

M. Frémy recently announced to the Academy of Sciences, of

* Comptes Rendus, 1880, t. XC., p. 701. † Comptes Rendus, 1882, t. XCIV., p. 1713.

Paris, the successful result of a second series of experiments to produce artificial rubies. By the former process the rubies were defective, but by the new process rubies one to two millimetres in size were produced, having the purity of the natural gem, and, like it, scratching topaz. M. Frémy's method was to fuse fluoride of borax and aluminum containing bichromate of potash. When under the continuous action of fire for fifty hours a porous and friable gangue was formed in the crucible. In this gangue the rubies appeared, and were separated from it by means of washing. M. Frémy reassures the jewelers by declaring that his discovery is of purely scientific interest, and will have no bearing on the trade in precious stones.

In *Nature*,* Mr. MacTear, of the St. Rollox Works, Glasgow, published some investigations by which he claimed he had produced artificial diamonds. Prof. N. S. Maskelyne found this claim to be unfounded; and this has been the case with other investigators, such as Cagniad de Latour and J. H. Gaunall, H. Depretz, Dr. Hare, Prof. Silliman, and M. de Chauconstois. In 1880 Mr. J. Ballantine Hannay read before the Royal Society a paper in which he claimed to have produced artificial diamonds after eighty dangerous experiments. He had obtained the results, he said, by tightly sealing in steel and iron tubes or coils, about four inches thick, some made by boring out a solid block of iron, containing 10 per cent bone oil and 90 per cent paraffine spirit, and subjecting these tubes to intense heat for some hours. After eighty experiments he produced fourteen milligrammes of residue, a part of which he called diamond. The substance exhibited to the Society was undoubtedly diamond, being pronounced such by Profs. Maskelyne, Roscoe, Stokes, and others. But none of it can be seen today in the British Museum cabinet; and as the specimens were of a fragmentary character, and not crystals, it is believed by many that although they were diamonds, they were never made by Mr. Hannay.

The four volumes on mining statistics, published by the Geological Survey, and edited first by Mr. Albert Williams, and now by Dr. David T. Day, contains an annual report on precious stones in the United States which has done much to awaken a wide-spread interest in this subject.

* Vol. XXI., January 1, 1880, p. 203.

MEETING 376.

A Study of Alternating Current Generators and Receivers.

BY PROF. WM. A. ANTHONY.

The 376th and annual meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, May 10th, at 8 P. M., Prof. C. R. Cross in the chair.

After the reading of the minutes of the previous meeting, the Nominating Committee presented their report, and officers were elected for the ensuing year.

The reports of the Executive Committee and the Permanent Meteorological Committee were then read and ordered placed upon the records.

The chairman then introduced Prof. Wm. A. Anthony, of Manchester, Conn., who read a paper entitled "A Study of Alternating Current Generators and Receivers." Prof. ANTHONY said: —

AT the time that I chose this subject not much had been done to popularize the study of alternating currents. Since then several papers have been read before various societies, and published in the various journals, and the mystery that surrounded the subject has to some extent been cleared up. There is still, however, much to be done to render the phenomena of alternating currents, in all their details, familiar even to electricians, and although some of the papers to which I refer have rendered unnecessary some of the work I had laid out to do, I believe I may still help a little to clear up the subject.

I shall devote my paper mainly to a study of alternating motors. I shall assume, as has been done in most cases in the discussion of alternating currents, that the changing E. M. Fs. may be represented by the simple curve of sines. Dr. Duncan, of Johns Hopkins University, has shown that this simple curve does not truly represent the real changes in machines in practical use, but I cannot see that the deviations he has noticed will vitiate the results I have reached in this paper.

Let us consider for a moment some simple cases of induction. A coil of wire lying in a horizontal plane is threaded by the lines of force of the magnetic field of the earth. Let it be turned to the vertical, and all these lines are discarded. While the wires of the coil are cutting across the lines of force an electromotive force is set up in the coil, which depends for its value upon two things, — the number of turns of wire in the coil and the rate at which lines are discarded from its area. The latter depends upon the rate of motion, the area of the coil, and the frequency of the lines. It is plain to see that, as the coil first leaves the horizontal plane, the rate of cutting is rather slow, and the E. M. F. set up is, therefore, feeble. The rate of cutting, however, increases, at first rapidly, and finally more slowly, until at the vertical the maximum rate is reached and the highest E. M. F. developed. Continuing the rotation, the E. M. F. falls, becomes zero when the coil reaches the horizontal, and goes through the same changes of value with the opposite sign, as the rotation continues through the other half of the revolution. It is plain to be seen, without any abstruse investigation, that the curve of sines must at least very nearly represent the changes of E. M. F.

A coil of wire carrying a current is a source of magnetic lines. Let such a coil be approached to another, and the lines of the first pass through the second coil, developing in it a temporary E. M. F., as though it were turned over in a magnetic field. Let the first coil be laid upon the second and then its circuit broken. The lines of force that did thread through both coils disappear, and an E. M. F. is developed as though the lines had been discarded by the rotation of the coil. When the circuit is closed the lines of force are gathered in again, and an E. M. F., opposite in direction to that before obtained, is developed. This is all well known to you, but it is well to think it over, and think out the curves that will represent the changes. Consider what takes place when we close the circuit. We know a current does not instantly start at its maximum value, but for an appreciable time is an increasing current: the law of increase must be something like the curve *ab*, Fig. 1. The rate of gathering in of lines of force must be represented by

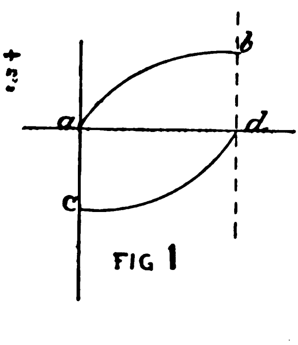


FIG 1

the same curve. Since the E. M. F. produced is a maximum when the lines are coming in most rapidly, it must be the greatest when the current begins, and will be represented by the curve *cd*, Fig. 1. That is, the E. M. F. leaps suddenly into existence at its maximum value, when the current begins, and dies away to zero when the current reaches its maximum. Now let the first coil carry an alternating current, represented by the sinuous line *abc*, Fig. 2. The E. M. F. developed in the second coil is rep-

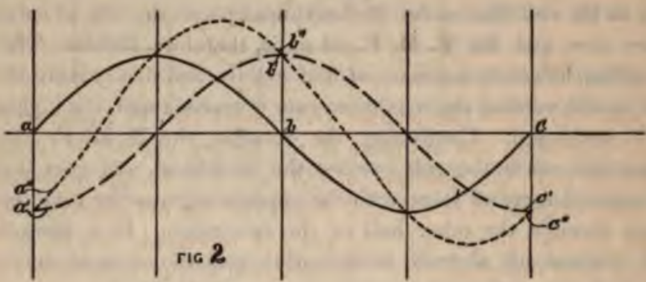


FIG 2

resented by the line *a'b'c'*, which *is behind the wave of current by one quarter of a complete wave length.* This is a most important fact, that any given phase of the induced E. M. F. occurs a quarter period later than the same phase of the magnetization. Not only is an E. M. F. induced in the secondary coil, but precisely the same effect is produced in the primary which carries the current, and this induced E. M. F. in the primary modifies in a very marked degree the current that would otherwise exist. I will ask your attention for a moment to a method of studying the effect of compounding the induced and impressed E. M. Fs., in fact, of compounding two or more E. M. Fs., whatever their origin.

In Fig. 2 the full line represents one alternating E. M. F., and the broken line another, behind the first in phase by a quarter period. The resultant E. M. F. is represented by the dotted line, which was obtained by taking the algebraic sum of the ordinates of the other curves; to this resultant E. M. F. corresponds the current that actually exists in the conductor.

I wish now to show how we may, in another manner, acquire a knowledge of the relation of the resultant to the component E. M. Fs.

Let OA, Fig. 3, revolve about the center O, A describing the circle. Its projections on the vertical will evidently give the ordinates of the

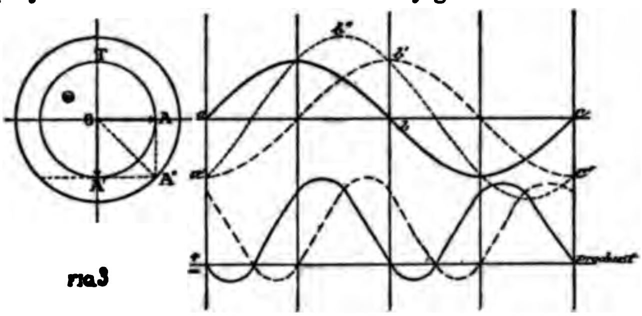


FIG. 3

full line curve. In like manner OA' behind OA, by a quarter revolution, determines the ordinates of the broken curve. It is easy to show that OA'', the resultant of OA and OA', by the principle of the parallelogram of forces, will determine the ordinates of the resultant curve. In short, if OA and OA' represents two E. M. Fs. in magnitude and phase, OA'', the diagonal of the parallelogram, of which OA and OA' are sides, represents their resultant in magnitude and phase. Both the curves and the parallelogram construction show the resultant as differing in phase from each of the components by one-eighth of a period, being behind the first and in advance of the second.

Take now the case of a coil of wire to which is applied an alternating E. M. F. It has been seen that the alternating current in the coil produces an induced E. M. F. This must be combined with the impressed E. M. F. to obtain the resultant which determines the current. We are now prepared to determine the relation of these three quantities. Suppose we know from the heating effect, or otherwise, what current flows through the coil. Knowing the resistance, we know also the *effective* E. M. F. required to maintain that current.

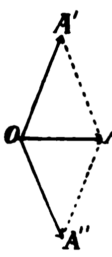


FIG. 4.

Let OA'', Fig. 4, represent this in magnitude and phase, OA', a quarter revolution behind the current line, is the line of induced E. M. F. Draw $A''A$ parallel to OA', make OA represent the magnitude of the impressed E. M. F., and complete the parallelogram. OA, OA', and OA'' represent the relations of the two components and their resultant. It is seen that the induced E. M. F. is nearly opposite the impressed, and that the effective E. M. F. is but a small fraction of either. It is well to

consider for a moment the relation of phases of the impressed and counter E. M. Fs. when these have different relative magnitudes.

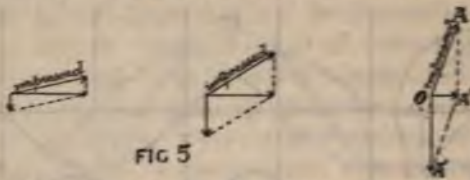


FIG 5

The several figures, Fig. 5, will show this. The impressed E. M. F. is the same in each case.

It is plain that, as the counter E. M. F. increases, its phase becomes more and more nearly opposite to that of the impressed E. M. F., and that the effective E. M. F., and, therefore, the current it will produce through a given resistance, becomes less.

The magnitude and phase of the resultant of any number of electromotive forces may be found by plotting the several components as the sides of a polygon. The resultant will be represented by the line necessary to complete the figure.

It is important now to consider how the energy of an alternating current may be represented. Referring again to Fig. 3, the dotted line represents a resultant wave of E. M. F. In a conductor whose resistance was one ohm the same line would represent the wave of current. The power represented by any E. M. F. and current is measured in watts by the current multiplied by the E. M. F. This is true of alternating as well as of continuous currents. If the E. M. F. and current are in the same direction, the product is positive, and work is being done to produce the current. If the E. M. F. and current are opposed the product is negative, and the current is doing work against the E. M. F. In the figures the power at any instant due to the E. M. F., represented by the line *abc*, and the current represented by the dotted line, is given by the product of the ordinates of the two curves for the instant considered.

In the lower part of the figure the ordinates of the full line represent these products. It is seen that, during the period of one complete alternation, there are two periods of positive and two of negative work; taking the algebraic sum of these and constructing a parallelogram upon the base *ac* equivalent in area to the remaining figure, the altitude of this parallelogram is the mean ordinate of the

curve of products, and represents the mean power of the machine during one period. Now, a very interesting and important principle is this, that this mean product is half the product of OA'' by the projection of OA upon the line of current. This furnishes a very simple and beautiful method of comparing powers due to the different component electromotive forces, for, since there is only one current, the powers of the several E. M. Fs. are directly proportional to their projections on the line of current. If the projection is opposed to the current, the power due to that E. M. F. is negative, and the current is doing work. If the projection is in the direction of the current, the power is positive and that E. M. F. is doing work to maintain the current. I shall have occasion presently to apply this to the study of the action of motors. But first I wish to call attention to one more condition that influences induction. I have spoken of this coil of wire as producing a magnetic field, and thereby setting up a wave of counter E. M. F. which lags behind the wave of current by a quarter period, and, therefore, neither absorbs nor produces power. I put inside the coil a mass of iron; the magnetic field and counter E. M. F. are greatly increased, and an investigation shows that the wave of magnetization no longer coincides with the wave of current, but lags behind it by an amount which depends on several factors, such as the quality of the iron, the degree of magnetization, etc., and the wave of counter E. M. F., which must be a quarter period behind the wave of magnetization is more than a quarter period behind the wave of current. Let us apply the graphical construction to this case. Let this line OA, Fig. 6, represent the current. If the resistance be one ohm it also represents the effective E. M. F. OM may represent the magnetization through the iron. OB, at right angles to OM, now represents the counter E. M. F., and completing the parallelogram by drawing BA, AC, and OC, OC represents the impressed E. M. F. The diagram discloses a very interesting fact. The projection of OB on the line of OA is OD opposite in direction to OA. *The current, therefore, does work against the E. M. F. OB.* This work is due to the magnetization of the iron, and appears as heat in its mass.

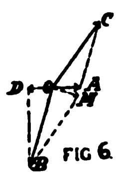


FIG 6.

To apply this to the study of alternating current motors, take the simplest case of two identical machines, one for a generator and the

other for a motor, each consisting of a coil of wire revolving in a uniform magnetic field. Let this coil A be the generator and B the motor. Suppose the currents generated in A, which are reversed twice in a revolution, to be led through B: while the current is in one direction B will tend to revolve, and if time be allowed for it to make half a revolution before the opposite phase of the current arrives, this would impel B in the same direction, and the revolution might be continuous. But if A revolves rapidly, the opposite phases of the current follow each other so rapidly that B will scarcely move in obedience to the first impulse before it receives a second impulse in the opposite direction. B, therefore, will not start by the action upon it of a rapidly alternating current. If, however, B can be put in motion, and brought into unison with A, it may, when left to itself, continue to revolve by the effect of the current. But now B, revolving with the same speed as A, develops an equal E. M. F., and since it is the resultant E. M. F. that develops the current in the system, it is necessary to consider what are the conditions under which A may be a generator and B a receiver. This our graphical construction will enable us to determine. Let OA', Fig. 7, represent the E. M. F. of the generator, and OA'' the E. M. F. of the motor. OA

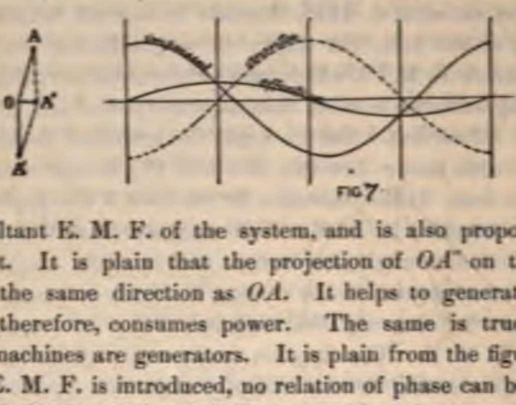


FIG 7

is the resultant E. M. F. of the system, and is also proportional to the current. It is plain that the projection of OA'' on the line of OA is in the same direction as OA. It helps to generate the current, and, therefore, consumes power. The same is true of OA', and both machines are generators. It is plain from the figure that, if no other E. M. F. is introduced, no relation of phase can be given to the equal E. M. Fs., OA' and OA'' that would make one a generator and the other a receiver. If they are opposite there is no current. In any other relation their projections on the line of current are in the direction of the current. But here comes in the E. M. F. of self-induction as a third E. M. F., to be combined with the other two

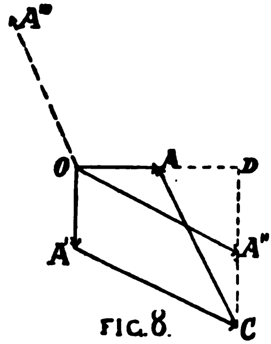


FIG. 8.

in determining the resultant. Let OA, Fig. 8, represent the resultant. Assume the rotation counter-clockwise, and leave out of account the retarding effect of the iron core, the E. M. F. of self-induction will be represented by a line 90° behind. Other things being equal, its magnitude varies with the current, and we may assume OA' to represent it for this particular case. The lines representing the E. M. F. of the generator, and the counter E. M. F. of the motor, must complete a polygon, and since they are equal they must be represented by two lines, such as $A'C$ and CA, or laying them off from O by OA'' and OA'''. Now, the projection of CA is opposed to the current, the current is doing work against it; CA is a counter E. M. F., and the machine to which it corresponds is a motor whose power is represented by the half product of OA by DA. If the load on the motor decrease, CA will approach opposition to $A'C$, A and A' approach O, the current represented by OA is diminished, and with it the power of the motor and the energy expended by the generator. This seems to me to be an example of an alternating current motor, which may be made as efficient as a continuous current motor under varying loads.

Here, however, is a case of a motor in which the relations are very different. CA, Fig. 9, represents the counter E. M. F. of the motor, and $\frac{OA \times DA}{2}$ its power. When the load on the motor diminishes, C moves to the left, diminishing AD, and so diminishing the product. But it will be seen that to maintain the necessary relation between the several quantities, OA, and, therefore, the current must increase, and more energy is consumed in heating the conductors when the motor is running light than when it is under load. But, although machines proportioned to give electromotive forces having the relations I at first indi-

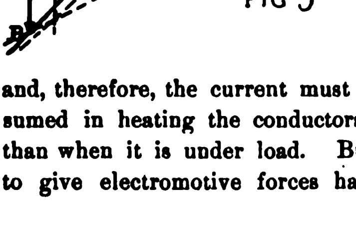


FIG 9

cated may make very efficient motors, there is this serious difficulty in their use, they will not start by the effect of the current. The problem that presents itself for solution is how to make an alternating current motor that will start when the current is turned on, will therefore have a determined direction of rotation and be fairly efficient. I believe there is no dynamo in commercial use that does not develop alternating currents. These are made continuous in the external circuit by means of a complicated and costly commutator, that is the troublesome member in the operation of the machine. When we use this continuous current to run a motor, by means of another costly commutator, we change it back to an alternating current in the motor coils. Is this double commutation necessary? Is there not some way to make use of the currents as they are developed in the generator coils, and so do away with both generator and motor commutators? This is a question that Mr. Nikola Tesla proposed to himself, and about a year ago undertook a series of experiments to obtain an answer. He is now ready to make public the results of his experiments, and through his kindness I am able to exhibit to you, tonight, one of his motors. This is the principle upon which the motor acts: an alternating current generator is constructed, having its coils so arranged that it may furnish two distinct alternating currents, whose undulations differ in phase by one quarter period.

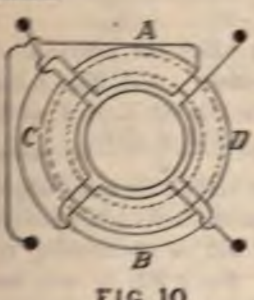


FIG 10

The method of utilizing these currents may be illustrated by Fig. 10. It consists of a ring of iron on which are wound four coils of wire, each covering one fourth the ring. Opposite coils are so connected that a current flowing through them develops north and south poles at diametrically opposite portions of the ring. One pair of coils is connected to one of the circuits. Current waves are produced in each pair in such relation that when the current in one is a maximum, the current in the other is zero. The current in one pair is, therefore, always increasing while that in the other is diminishing, and the magnetic poles due to these currents follow the same changes of intensity. Suppose at a given instant north poles are pro-

duced at A and C, and south poles at B and D, and that C and D are increasing while A and B are diminishing. When C and D reach a maximum, A and B are zero. Then C and D diminish and A and B increase with reversed polarity. The effect of this is that resultant poles travel around the ring in the direction $A\ C\ B\ D$. Practically, it is a rotating magnetic field without mechanical motion. If now we put inside the ring a cylinder of iron, free to rotate on an axis coincident with the axis of the ring, the iron will begin to revolve, and will tend to reach a speed equal to that of the field rotating around it. To understand the rotation it must be borne in mind that in all iron there is a certain "coercive force" that opposes magnetic change within it. In consequence of this the magnetism induced in the iron by the rotating field lags behind the field, and the iron is dragged along, as it were, by a magnetic friction. If the iron were absolutely soft and free from coercive force, it would not rotate. If it were so hard that magnetism once induced in it was permanently fixed, it would not rotate unless the rotation of the field were very slow. To produce good results the iron must, therefore, be neither too soft nor too hard. But we can do better than to try to obtain iron of a given degree of hardness: we may use the softest iron and wind upon it coils of wire, forming closed circuits. The currents induced in these coils, as the field revolves, have an effect similar to that of the hardness of the iron in causing a lagging of the induced magnetism in the core, and the latter is, therefore, dragged along by the rotating field.

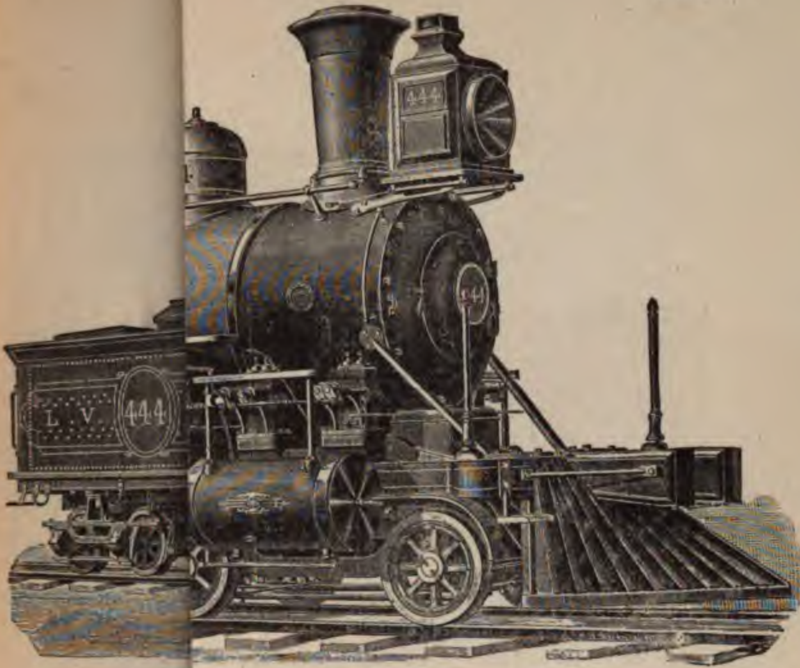
The motor which I have here on the table has such an armature as I have just described. Mr. Tesla very kindly loaned it to me for this occasion, and I am glad to be able to give you a practical demonstration of the operation of motors as I have described. [The motor was then shown in operation.] Remember that the wire on this armature forms closed circuits. It has no communication with the wires outside. These connect to the stationary field coils. There is no commutator, no sliding contact even. There is nothing about the machine to require attention, except the bearings. Bearing all this in mind, I think the result you have seen is sufficiently remarkable.

The meeting closed with a vote of thanks to the speaker for his very interesting and instructive lecture.

Plate I.

ombustion Chamber.

Plate I.



ombustion Chamber.

Plate III.

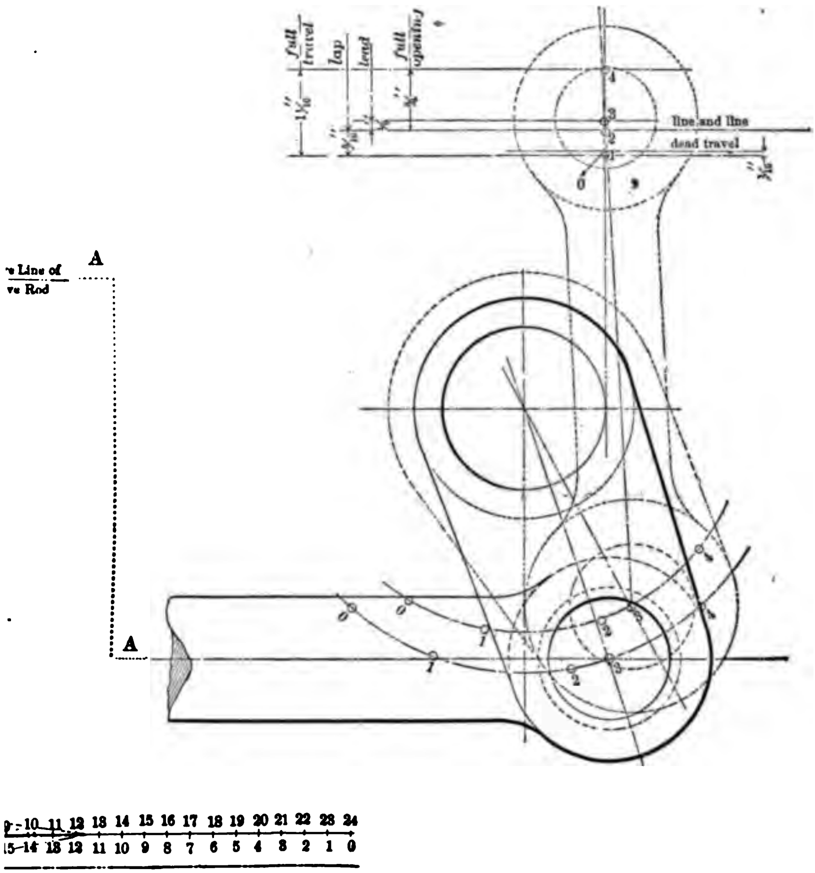
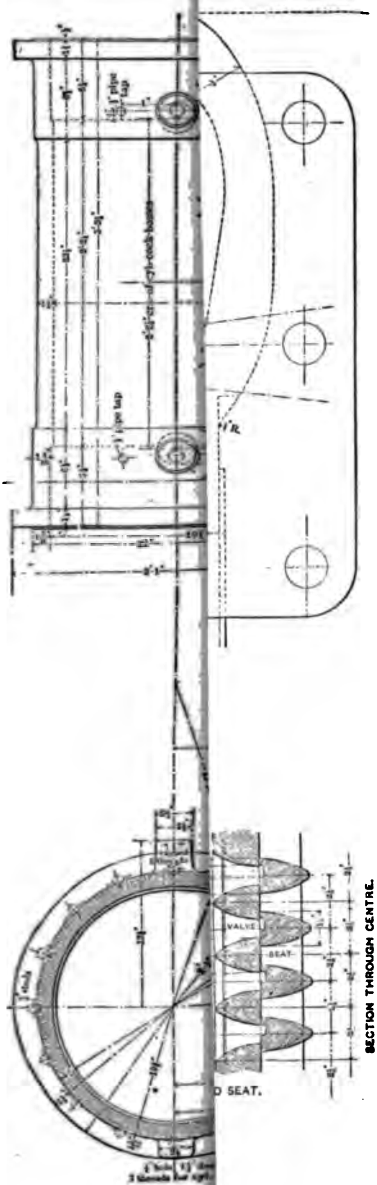

full travel
lap
lead
full opening
line and line
dead travel
Line of
Rod
A
A

Plate IV.



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CONTENTS.

NOTICE.

The Society of Arts, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce.

Regular meetings are held semi-monthly from October to May, inclusive, in the Institute Building; and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending October 1, 1889, most of the business portions of the records being omitted.

The thanks of the Society are due to the Massachusetts Railroad Commissioners for the loan of the electrotypes used in illustrating Prof. Lanza's paper on "Heating Passenger Cars by Steam from the Locomotive;" to the Writing Telegraph Company for those illustrating Mr. Gump's paper on "Transmitting Handwriting by Electricity;" to Dr. M. G. Parker for those illustrating his paper on "Peculiar Rotary Motions found in Lightning and other Electrical Currents;" to Mr. Henry G. Kittredge for that illustrating his paper on "Cotton Culture in Central Asia;" and to the Welsbach Incandescent Gas Light Company for those illustrating Prof. Shapleigh's paper on "Gas Lighting by Incandescence."

For the opinions advanced by any of the speakers the Society assumes no responsibility.

LINUS FAUNCE,
Secretary.

Boston, August, 1889.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-SEVENTH YEAR.

MEETING 377.

Heating Passenger Cars by Steam from the Locomotive.

BY PROF. GAETANO LANZA.

The 377th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 11th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Prof. Gaetano Lanza, of the Institute, who read a paper on "Heating Passenger Cars by Steam from the Locomotive."

Prof. LANZA first stated that the substance of his paper was taken from his recent report to the Railroad Commissioners of this State. He then said: While the railroad companies in this State are nominally using, as a rule, some one or more of the so-called systems, they have in many cases been trying the different appliances, more or less regardless of the systems, and the subject will be treated in this paper from the latter point of view, the different methods for accomplishing any one special object being discussed together, and not as forming a part of a certain so-called system.

We may, therefore, classify the subjects to be considered as follows: —

1. The means of coupling the steam pipes of the cars together.
2. The means of reducing the locomotive pressure before it reaches the train.
3. The means of disposing of the condensation.
4. The proper piping in the cars to give the necessary radiating surface, and freedom of circulation.

5. The proper valves to be used.
6. The disposition of the main steam pipe.
7. The use of live steam, exhaust steam, or water.
8. Auxiliary boilers under the cars.
9. Means of regulating the heat in moderate weather.
10. Means of taking care of cars when stored away.
11. Tests to determine the amount of steam used.

COUPLINGS.

There is a large number of steam couplings in the market, each so-called system having a different one. Indeed, it might be said that the differences in the couplings form one of the most distinctive features of the systems. No detailed description of them is necessary, but the following distinguishing features should be mentioned:—

While the greater part depend for flexibility on a flexible rubber hose, there are some which claim as a specially good feature that they are made entirely of metal. Such couplings depend for their flexibility upon ball joints and slip joints. Experience has shown that they wear out and leak badly in a very short time, so that this class of couplings may be pronounced unsuitable.

A feature which exists in a number of couplings, and is undoubtedly good, is the property of automatically uncoupling whenever the cars break apart. This feature is enjoyed by the Sewall, the Westinghouse, and some other couplings. In this class, also, each part of the coupling is attached to a piece of hose attached to the main train pipe of each car, and these couplings should be, and generally are, interchangeable, each half being like the other half. The tightness in such couplings is insured by the force of gravity causing the rubber gaskets, which should be of hard rubber, or some similar composition, to press against each other. Such couplings need a certain length of hose, and, of course, form a pocket between the cars which might be supposed to collect condensation water, but which, as far as observed, does not present this difficulty.

Some couplings consist of one piece of hose intermediate between two metallic portions to which it is permanently attached, so that this entire portion can be taken off without making up any joints. These couplings have either metallic surfaces in contact, or else rubber gaskets, and are usually made tight by means of a screw. If the train were to break apart they would not uncouple, but would have

to break. Moreover, it does not seem probable that a metallic joint can be kept as tight as a gasket, unless it be more carefully handled than it is likely to be in the regular service of a railroad.

In conclusion, it is very important that all those roads that are at all likely to interchange cars should adopt the same coupling, even though they have nothing else alike.

The following considerations favor the adoption of the Westinghouse air-brake coupling: —

The train hands are all familiar with its management.

The patent expires shortly, and the payment of royalty would be avoided.

The three-quarter inch coupling, now used for the air-brake, would doubtless be too small, and it would be necessary to adopt the one and one half inch coupling. Also, it would be necessary to have the gaskets made of hard rubber or of some similar compound, and not of soft rubber. The Boston and Albany and the New York and New England railroads have already tried the Westinghouse couplings, and they work well.

REDUCING VALVES.

In regard to the means for reducing the pressure of the steam before it reaches the train, the most primitive way is to introduce into the pipe leading to the train an ordinary globe valve, and to require the engineer to regulate it by hand, so as to produce the proper pressure on the train. Some do this from choice, and others because they have been unable to find a reducing valve that did not get out of order. Some of those who use a globe valve add a safety valve, which blows off at a certain pressure, and thus warns the engineer that the globe valve wants attention. Nevertheless, the proper way to accomplish the object is to introduce into the pipe a reducing valve, which, when once set, will keep the pressure on the train uniform without the necessity of constant adjustment by the engineer.

There are many reducing valves in the market, but when they are subjected to high pressures, and not handled with more than ordinary care, they too often fail. This failure is often due to their extreme delicacy, and to the difficulty in keeping lubricated certain parts which are exposed to very high temperatures and require specially good lubrication. These valves generally have some kind

of flexible diaphragm, and the possibility of making such a valve succeed, under trying circumstances and long usage, is questionable. On the other hand, valves composed of pistons of different sizes have been tried, but not to any great extent, and the most that can be said is that there is promise of success in this quarter.

TRAPS.

The means of disposing of the condensation without letting it freeze, and thus burst the pipes or other connections, is one of the most serious questions of all those connected with steam heating. Even the so-called frost-proof traps freeze up at times.

First, as to the object of any trap.

In some of the so-called systems the steam is taken into each car from a cross or a T in the main steam pipe under or in the floor of the car, and that portion which condenses in any one car must be drained from that car, and does not pass into the next. Of course the draining can be accomplished by means of a simple globe valve, without any trap at all, but if this is done the following difficulties are met:—

If the valve is closed while the train is running, too much condensation water may collect before it can be let out, thus getting water into the main pipe and preventing a good circulation of the steam, and, at the same time, permitting the condensation to cool in the lower part of the pipe, and perhaps even freeze and burst the pipe. If, on the other hand, the globe valve is left open enough to avoid the above-described dangers, there is leakage and consequent waste of steam, and this may amount to a good deal, especially when the jarring of the train causes the globe valve to open wider during the run. These objections become serious on through trains, and in all cases where the times between stations are long and the stops short, and where the management of the valves is intrusted to green hands; but on roads where the times between stations are short, and where the work is only intrusted to well-drilled hands, the objections stated above are not valid. Thus on the Connecticut River road and on the Boston, Revere Beach, and Lynn there is no trouble of this sort, and traps could easily be dispensed with. Indeed, there is never any difficulty with frozen traps in the case of roads where the cars are kept warm all the time, whether running or standing still; but

there is difficulty when cars have to be left for long periods in the cold with no heat supply. By the Martin, the Emerson, and several other systems, each car is drained separately.

In the Sewall system the steam passes from the main pipe into a valve in the middle of the car. If this valve is wide open the whole, and if partly open a part, of the steam passes through the car back to the main pipe, from which the condensation may be drained off by a trap or by the globe valve if it is open wide enough. If the trap or valve is closed the whole of the condensation is forced back into the rear car, and from the end of the main pipe of the rear car it is blown out. This is the method most commonly used on the Old Colony and the Fitchburg railroads during the run, both of these roads using the new style Sewall valve. If the valve or trap is partially open a part is disposed of in each way. When the old style valve is used they are more likely to depend upon the trap to drain the entire condensation of the car. When the condensation is all forced back, and globe valves are used instead of traps, it is customary to make use of the valves only on two occasions: —

(*a*). On heating up, to drain the condensation when the steam first starts through the car.

(*b*). On putting the cars away, to drain the main pipe thoroughly, so as to avoid all danger of freezing. For these purposes the globe valve works much better than the trap, as the latter does not furnish a sufficiently free exit for the steam, and freezing ensues when the cars are exposed without heat. There is an increasing tendency with those who use the Sewall system to discard the Sewall trap and use a plain globe valve. This is done on the Fitchburg and on the Old Colony roads.

The idea at the basis of most of the traps, whether those used to drain the main pipe or the car, is that the contraction and the expansion of some expansible metal or liquid, due to different degrees of temperature, shall respectively open and close the valve,— thus opening to let out the water, but closing to keep in the steam. This is effected by causing the trap to close at a certain fixed temperature, which, if the steam in the car were at atmospheric pressure, would be 212 degrees Fahrenheit.

The operation of the trap is supposed to be as follows: While the pipes are full of steam, so that the expansible metal is exposed

to the temperature of the steam, it expands, closing the valve, and the trap is closed; but when the steam condenses so that a certain amount of condensation water collects in the bottom of the pipes, this water comes in contact with the expansible metal. As this water at first is practically at the temperature of the steam, the trap does not open immediately, but when the water nearest the trap cools down, the expansible metal contracts, the valve opens, and the water escapes. As soon as steam replaces the water, the metal is supposed to expand again and close the valve. The principal difficulty with these traps seems to be that, when the cars are set off in a cool place, they either do not act promptly enough, or else the little slow drip freezes on its way out, and, the passages being narrow, the trap gets frozen up, and also the pipes, and hence the steam, when let on again, does not get through. An attempt has been made to remedy this difficulty by means of the so-called frost-proof traps, which have an opening at the top as well as at the bottom, so that even if the lower orifice is frozen, the upper one will furnish an outlet for the steam when it first comes in, until the lower one is thawed out and performs its functions properly. These traps have succeeded, on the whole, rather better than the others, but they can hardly yet be pronounced a success.

The various traps in use may be classified as follows:—

(*a*). A species of box trap, such as the Sewall or the Curtis.

(*b*). A species of trap known as the thermostatic trap, which may be illustrated by the Martin, or by a trap devised and used by Mr. Henney, superintendent of motive power of the New York and New England Railroad.

Both kinds have similar troubles, and at times freeze up.

There is another way of taking care of the water of condensation, which, though it has not yet had an extensive trial, seems to afford the means of avoiding frozen traps. It is the method adopted by Mr. George A. Houston, of the Atchison, Topeka, and Santa Fe Railroad. The method which he has been using the past winter consists in having under the car a tank into which the condensation falls, and from near the bottom of this tank proceeds a small pipe running up into the car, and emptying at the top into a tank above the floor and within the car. The action is as follows: At first, on beginning to heat up, all the pipes and both tanks are full of steam. As soon

as condensation has taken place, sufficient to seal the entrance to the small pipe, the steam in the upper tank is separated from the other. Then, on cooling, the pressure decreases and the excess of pressure in the lower tank sends the water up into the upper tank. The original idea of putting the tank under the car was to make it serve as an auxiliary boiler, but Mr. Houston, recognizing the objections to having a tank under the car, is now fitting up a large number of cars with a similar device, where, however, there is no auxiliary boiler, and where, in place of the lower tank, there is a small box or trap just below the upper floor, from which proceeds the small pipe, and the upper tank is not set on the floor, but somewhat higher up. The effect of this is that the condensation water is collected in this upper tank, and thus it is in no danger of freezing, and also it gives out some heat through the walls of the tank into the car. It also furnishes hot water for cleaning up. When the car is set off, a sufficient number of valves are opened wide, and the water is all drained off.

No system of draining off the condensation water can be efficient without the means of properly venting the pipes and letting in air.

MAIN PIPE; RADIATING PIPES AND VALVES.

It seems to be most common to use one and one-half inch pipe for the main pipe. Some have used one and one-fourth inch, but one and one-half inch is more common, and gives better satisfaction generally. As to the location of this pipe, it is most frequently placed under the middle of the car, wrapped, of course, in hair, felt, or some other non-conducting covering. A better way is to place it between the sills and box it in. In this case it is also wrapped, and the surrounding woodwork should be protected by tin or sheet iron. Another and a better way yet is to place it inside the car on one or both sides. In this case it is not wrapped, but forms part of the radiating surface. The chief objection to this last arrangement is that the heat cannot be entirely shut off from one car without shutting it off from all the cars behind it. Another objection is that the passages are a little more crooked, but this is more than counterbalanced by gain in heating power.

On account of the exposed conditions of the car the radiating surface should be considerably more than would be required in a

building. On the Boston and Albany road they have one square foot of heating surface for each twenty-five cubic feet of space in the car, or one square foot of heating surface for every thirteen square feet of exposed surface, including floor, roof, and walls. Of the 2265 square feet of exposed surface 240 are glass. On the Old Colony road they have one square foot of heating surface for each twenty-six cubic feet of space in the car, or one square foot of heating surface for each thirteen and four-tenths square feet of exposed surface. Of the 2344 square feet of exposed surface 277 are glass. The above are reasonable proportions.

In regard to the size of the pipes to be used for radiating pipes an opinion based upon experiment cannot be given. As the following conclusions are based on observations only, they may be imperfect. It is desirable to so arrange the pipes that there may be as little obstruction as possible to the flow of steam. It is probable, therefore, that one and one-half inch pipe is better than one and one-fourth inch, and two inch pipe better than one and one-half inch. The larger the pipe also the shorter will be the length of pipe needed. Moreover, there is reason to believe that where two inch pipes are used the time of heating up is less than where one and one-fourth inch pipes are used, and also that the proportion of the pressure realized in the last car is greater. Nevertheless, in the cases of one and one-fourth inch pipe which have been examined there have been other causes for an increased resistance. Hence it may be that all necessary freedom of circulation can be secured with one and one-fourth inch pipe, though indications point to two inch pipe as preferable.

The connection between the main steam pipe and the radiating pipes should be as free as possible, and it is desirable that the steam should not have to pass through the radiating pipes of one car before entering the main pipe of the next. So also the condensation of each car should be drained off from that car and not returned to the main pipe. The most primitive way is to have in the main pipe near the middle of each car a cross from which proceed the pipes that lead steam into the radiating pipes on each side of the car; then a globe valve is placed in the main pipe on each side of the cross, its only use being to shut off the rear end of the main pipe when the car is the last car in the train.

Such a system works all right if proper care is taken of it, but it is desirable to reduce the number of valves needing attention, and also the danger of leakage by the use of some more complicated single valve, which can perform the necessary service, and at the same time be more free from liability to leak. In choosing between the different devices, the amount of the reduction of pressure of steam in its passage through the train is therefore a most important consideration, and this should be as small as possible.

A train should be heated without having high pressure steam on any car, for if, in order to get sufficient heat into the rear car, it is necessary to have a very high pressure in the first car, in that car there will be the danger of an explosion or of blowing off an end. This consideration also enforces the importance of freedom from resistance. The above is also a reason why a good and reliable reducing valve is a desideratum.

EXHAUST STEAM, LIVE STEAM OR WATER.

The main difficulty with any system of heating by means of water stored in a reservoir, and heated up by steam outside or inside of it, is the length of time required to heat up the cars in cold weather, because while the steam is heating the water it cannot be heating the car to the same extent as it would if not required to heat the water. A hot-water circulation seems to be better adapted either to heating in moderate weather, or else in cases where individual heaters, like the Baker or Johnson heater, are used and fire is kept in them nearly all the time.

Exhaust steam is very much needed in the locomotive to generate the draught, and it is certainly a serious question whether any of it can be spared to heat the train.

Any system which attempts to heat with exhaust steam is liable either to cause back pressure on the cylinder, or else to spoil the draught. Either of these results is very detrimental to the running of the locomotive. Mr. Houston, of the Atchison, Topeka, and Santa Fe Railroad, has used a system utilizing exhaust steam, which is open to the above objections to a slight degree only, if at all. The steam is taken from a point about half way down the exhaust nozzle by a pipe, and enters the pipe in the direction of its flow, thus utilizing its velocity to send it into the train pipe. A series of check valves retain the maximum pressure in the train.

He also uses a peculiar valve by means of which exhaust steam is admitted whenever the throttle valve is open, and whenever the throttle is closed live steam is used, so that the heating up is all done with live and not exhaust steam; and it is perfectly possible at any moment to shut off the exhaust steam and admit live steam instead.

The system, at the time when the examination was made, had been run on three cars in line only, and is reported to have succeeded in the very coldest weather in heating them thoroughly. Whether there will be sufficient exhaust steam to spare to heat a line of eight or ten or twelve cars is not yet demonstrated, nor have any tests yet been made to determine the effect, if any, upon the back pressure or upon the draught, though none has been noticed in the running of the engine.

Another difficulty is that when exhaust steam is used oil is liable to get into the pipes and valves, which therefore need frequent cleaning.

All the above leads to the conclusion that the main reliance must be upon live steam, with a possible use of exhaust steam when, and if, it can be spared.

No return system has been investigated, as none is used on the railroads of the State.

AUXILIARY BOILERS.

The roads that have auxiliary boilers under their cars are making less and less use of them. The plan of having the fire under the car is believed to be radically wrong and more dangerous than a fire in the cars, for it is not accessible during the run, and if the train is stalled in a snow-drift the auxiliary boiler becomes practically useless.

REGULATION OF HEAT IN MODERATE WEATHER.

There is not in use on the Massachusetts roads any successful device for regulating the heat in moderate weather other than by shutting off the steam and opening the ventilators and windows. Mr. Houston has a scheme in contemplation, but has not yet put it in practical operation, and one has been in use the past winter on the Chicago, Milwaukee, and St. Paul, but no personal examination of it has been made.

CARE OF CARS WHEN STORED AWAY.

As the locomotive generally cannot be attached to cars for such length of time before they are to start as will be required to heat

them, it will be necessary at all the principal stations, and, perhaps, at all the stations where cars are left, that there should be either a stationary boiler, or else one or more locomotives specially devoted to heating cars, and that pipes or hose should lead from the boiler to those points where cars will stand when they are to be heated. For this purpose an ordinary low-pressure boiler would be sufficient, and it could also be used to heat the station.

This method is adopted by the Boston and Albany at Boston and Springfield, and by the Connecticut River at Springfield. It would certainly be the method to be adopted by most roads at all stations where they have occasion to leave cars in the cold for any length of time. Some roads, especially the Old Colony, are, however, obliged to leave cars at so many stations that it would be at least a hardship to be obliged to have a stationary boiler at each one of them.

It is an open question whether there is any other feasible means of heating up cars at the smaller stations where only two or three cars are left.

It having been suggested that oil stoves might be used for this purpose, some experiments were made to determine their heating powers, with results which were not encouraging. The odor also would be objectionable if they were not properly trimmed.

AMOUNT OF STEAM USED IN HEATING CARS.

There are all sorts of opinions and statements in regard to the amount of steam taken from the locomotive to do the heating. Some claim that the steam cannot be spared, and that the engine cannot make her time if called on for this extra duty, and others that it makes no perceptible difference in the running of the locomotive. Some even go so far as to say that all the steam required for heating can be furnished through a hole in the boiler no larger than a pin-hole. That neither extreme is correct is shown by the following experiments. It did not seem to be worth while to undertake any very precise work to compare the amount of steam used, when this, that, or the other appliance is used, or this, that, or the other size or amount of pipe, for it does not seem that, in the present stage of development of steam-heating, such information is required.

The winter was so far advanced when the investigation began that there was not sufficient time to perform the work in such manner

as to obtain indications as to the effect of each appliance upon the amount of steam used, and, moreover, at the beginning it was not at all certain whether the amount of steam used would form an element of any importance in the question.

Such an investigation would have involved some very careful work in getting the same conditions of temperature outside and inside of the cars, and also in studying the effect of the wind. Other conditions also would have been required, which would have been at best difficult to obtain, and which could only have been obtained, if at all, with an empty train, and, if this were used, the results would not be those of practice.

The attempt, therefore, has been made to obtain, as nearly as may be, the amount of steam used in an ordinary run in cold weather, leaving the train hands to manage the heating, as they usually do, which means that the cars are sometimes too hot and sometimes too cool, but generally somewhere near right. It also means that if they become too hot they will be cooled off, either by shutting off steam or by opening ventilators or windows.

In view of all the above, the problem has been to determine, approximately, the amount of steam used with sufficient exactness to show whether it is likely to be a serious tax upon the locomotive. The apparatus used consisted of two lengths of six inch flange pipe, as shown in the accompanying cuts, bolted together with a brass disk between them,— this disk containing a two inch hole, into which is screwed a nicely-made circular orifice. The steam enters the apparatus at one end and passes through the orifice, and then from the other end of the apparatus it passes into the main train pipe. The pressures in the different parts are regulated by two globe valves,— the first controlling the admission of the steam to the apparatus, and the second placed just beyond the apparatus, to control its pressure on the train, so as to make it correspond to that ordinarily used. The pressures on each side of the orifice were shown by test gauges, and these and also the boiler gauge were read every five minutes during the run. Afterwards, when the engine was in the round-house, the same conditions were repeated as nearly as possible, with the following exceptions: —

Instead of delivering the steam into the train-pipe it was delivered into a short pipe with another globe valve, which regulated its

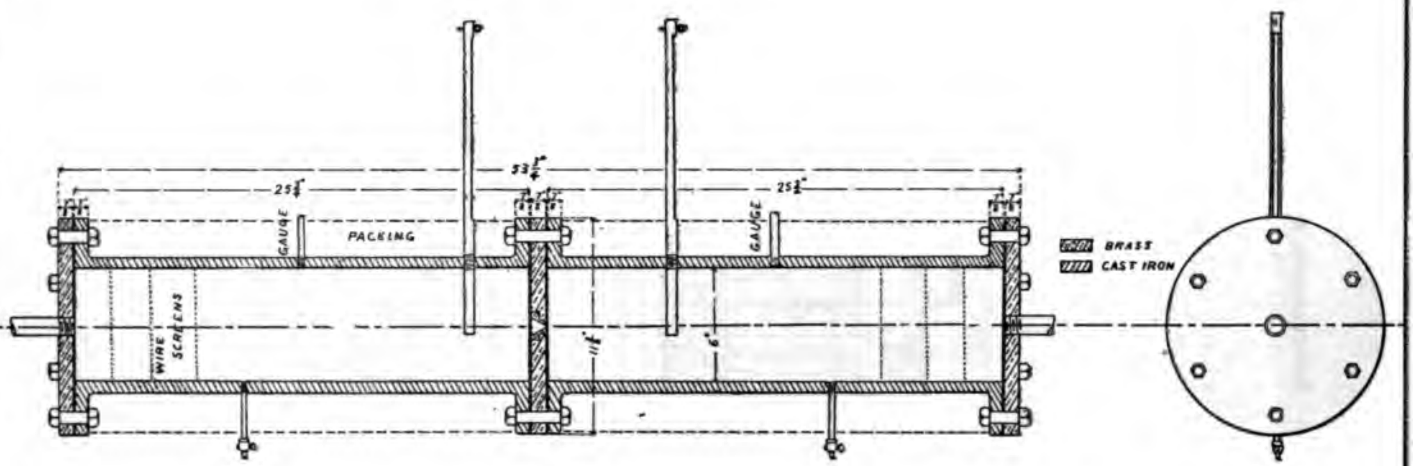
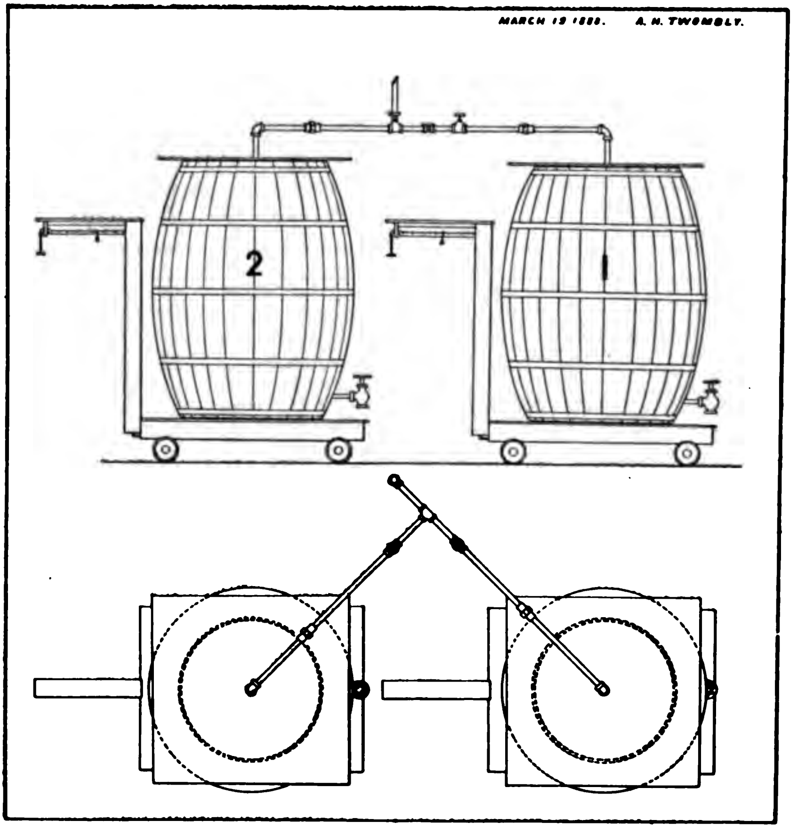

GAUGE
PACKING
GAUGE
BRASS
CAST IRON
WIRE
SCREENS
6"

PLATE 2.



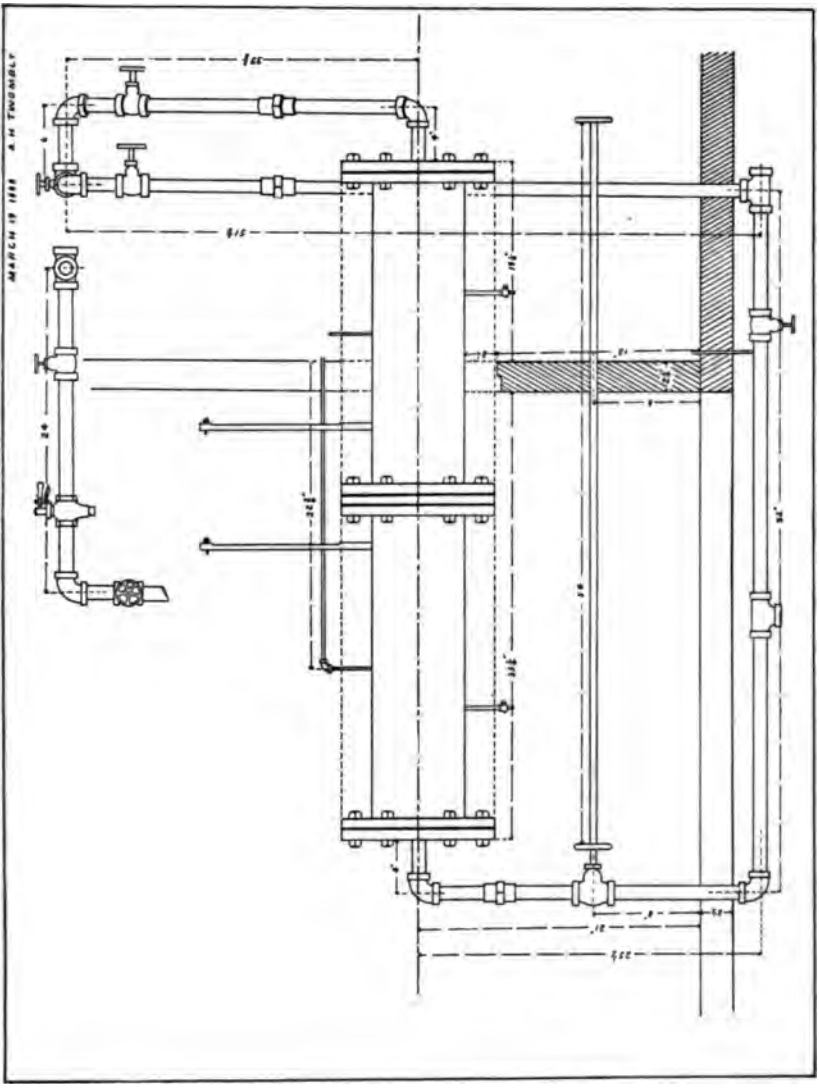


PLATE 3

pressure in this pipe to correspond with the pressure on the train. The prolongation of this pipe extended into a barrel partly full of cold water, where it was condensed and weighed. The steam for the train being taken from the dome, it was assumed to be dry. At any rate, it did not seem to be worth while, at that stage of the problem, to test it with a calorimeter.

The steam was taken from the combination from which proceed all the pipes that take steam from the locomotive except the dry pipe. It is probable that the results were somewhat affected by the current in each of these pipes, which was, of course, more or less irregular; but these irregularities are precisely those which occurred on the run.

The boat train on the Old Colony road and its locomotive, which Mr. Lauder kindly consented to have used for the experiment, was at the time running with four steam-heated cars, viz.: a combination baggage and second-class car, a smoker, and two passenger cars, all fitted with the Sewall system, including the Sewall coupling and the new Sewall valve.

The four cars stated above are first heated up by the engine, which is generally attached about 3 P. M. The train leaves the yard at 5.10 P. M., reaches the depot at 5.30 P. M., where it remains without the engine for half an hour, and starts at 6 P. M. for Fall River, arriving there about 7.20 P. M.

There are, therefore, four cars in line during the heating up. When the train leaves the depot, however, two baggage cars are placed between the combination car and the engine. One of these cars is a platform and the other a box car. They are not heated by steam, but each has a steam pipe passing underneath, so that the steam has to pass through this pipe the length of these two cars before entering the four steam-heated cars. The preliminary experiment to determine the size of orifice required in our apparatus was made on February 28, 1888.

An orifice one-eighth inch diameter was put in, and on trying to heat up the cars in the afternoon, by letting the steam pass through this orifice, it soon became evident that they could not be heated in any reasonable time, if at all, so the apparatus was cut out of the circuit, and the train was heated up in the usual way.

The experiment was then made to see if the one-eighth inch orifice would be large enough to use on the run; but as forty pounds

pressure was needed on the train pipe in the cab, and as it was not possible to get more than five by the use of that orifice, it was demonstrated that an orifice one-eighth inch diameter was too small for the four cars. Next, a one-half inch orifice was substituted for the one-eighth inch, and this worked all right. It was none too large; and it is probable that if the experiment had been made with six cars, with the thermometor below zero, a larger orifice yet would have been needed. As it was, the one-half inch orifice was used in all the tests. These experiments showed the amount of steam used per hour, on each trip, as follows: —

First trip, 4 cars thoroughly heated, . .	334 lbs.	27°	outside.
Second trip, 4 cars well heated, ...	306 "	27°	"
Third trip, 5 cars insufficiently heated, .	326 "	30°	"
Fourth trip, 5 cars poorly heated, . . .	380 "	19°	"

The experiments, though not made with an extreme degree of accuracy, nevertheless give the results to be expected in practice with steam-heated cars fitted up like those experimented upon with a sufficient degree of approximation to justify an opinion as to the tax upon the power of the locomotive, and they indicate that the amount of steam required is by no means inappreciable, and, on the other hand, that this amount is not, as a rule, a serious tax upon the locomotive, especially in view of the fact that at the time when steam heating is most needed, *i. e.*, in the coldest weather, the travel on most roads is light.

The result of all these experiments will undoubtedly be a more extended use of continuous heating during the coming winter, and a general improvement in the appliances and in the management of the apparatus. The following conclusions may fairly be drawn from what has been done: —

It is very important that there should be uniformity in couplers. The Westinghouse air-brake one and one-half inch coupling, with a hard rubber gasket, works satisfactorily, railroad employees are familiar with its use, and the patent upon it expires shortly.

In regard to everything else, uniformity is not so imperative.

The main pipe should be as well-protected as possible. If it must be outside the car it should be thoroughly wrapped. A better place for it is between the sills, and in that place, also, it should be

wrapped, or it may be placed inside the car, as is done to some extent by Mr. Richards, of the Boston and Providence Railroad, and by Mr. Henney, of the New York and New England Railroad.

The main pipe, the valves connecting this with the radiating pipes, and the entire system of radiating pipes, should be such as to offer the least possible resistance to the flow of the steam, so that high steam pressure shall not be required on the train. A two inch or at least a one and one-half inch pipe is desirable to meet this requirement.

A reducing valve which is not liable to get out of order and let high pressure on the cars is a great desideratum.

The amount of radiating surface generally adopted, and which seems to be sufficient, is about one square foot for each twenty-five cubic feet of capacity of the car.

The trap should be protected from freezing, and the best way is to have it inside the car. The trap introduced by Mr. George A. Houston, on the Atchison, Topeka, and Santa Fe is recommended for examination and trial.

It seems probable that auxiliary boilers under the cars can be dispensed with in this State.

Stations where cars are left should generally be provided with a stationary boiler and pipes for heating the cars.

The amount of steam required is neither excessive nor inappreciable. Nevertheless, the question of economy will be an important element in deciding upon the nature of the appliances to be used when it is desired to heat trains of ten or twelve cars. As a rule, the time when the most steam is needed for heating is the very time when travel is the lightest, and hence when the steam can best be spared.

It is desirable that there should be some automatic device for regulating the heat.

MEETING 378.

The Eco-Magneto Watchman's Clock.

BY MR. CHARLES A. WHITE.

Transmitting Handwriting by Electricity.

BY MR. W. E. GUMP.

The 378th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 25th, at 8 P.M., President Walker in the chair.

After the reading of the records of the previous meeting, and the election of new members, the President introduced Mr. Charles A. White, of Boston, who exhibited and described the "Eco-Magneto Watchman's Clock."

Mr. WHITE said: Only a few years ago, an electrical device for recording the movements of watchmen was not known, but the efforts of property owners, insurance companies, and others to make themselves more secure against losses by fire, flood, thieves, etc., or, in fact, to assure themselves of the faithful performance of their duty by watchmen, have led inventors to conceive various devices by which such an end might be gained.

The result has been that today there are many such devices, some mechanical, but mostly electrical, and all, perhaps, more or less liable to criticism, as being too complicated, too delicate in construction, or subject to manipulation by the watchman.

Until now, the electricity in all electric watch clocks has been generated by chemical batteries, which, in themselves, are a constant source of trouble and expense, even to electricians, and a profound mystery to very many people; but the great trouble with these clocks worked by chemical batteries is that they can be so easily manipulated by watchmen, to make false records, and the slightest accident to any part renders the whole system useless.

Now, it is evident that what was needed was a device operated by electricity, that would work strongly and surely, that could not be operated by any method of crossing wires, or by circuits closed anywhere on the wires, that required no delicate springs or the services

of electricians to maintain. Several years ago, Mr. Fessenden invented an electric watch clock, worked by chemical batteries, but after repeated troubles with the batteries it was abandoned, and he has since produced the eco-magneto watchman's clock, which is here exhibited.

In this clock the batteries are entirely dispensed with, permanent magnets being used instead, and the electricity is generated by the act of recording a visit at station, on the same principle that one rings a telephone call by means of a magneto, except that only a partial turn is necessary to make a record. When the key is turned, it causes the armature to revolve rapidly within its field of magnetism, and the current thus generated produces a vibration of the armature in the clock, which causes a short arm, containing the needle, to puncture the paper dial, which is carried round by the mechanism of the clock twice in twenty-four hours. The radial lines on the dial correspond to the divisions of time into hours and minutes, while the concentric lines denote the position of the station. An important feature of this apparatus is that it is entirely free from any chance of false records being made, as each station is worked distinctly and separately from all others, and there is no electricity in any part of the system except at the moment of making the record. The record cannot be made in any other way except from the several stations, and it is impossible to make a record by any method of crossing wires, or other devices employed by unfaithful watchmen, in other forms of electric clocks. Another feature is its extreme simplicity; there is nothing to get out of order; the magnets are perpetual, and it requires no skilled electrician to set it up or maintain it. Still another is the fact that recovery after a record is made entirely by gravity.

TRANSMITTING HANDWRITING BY ELECTRICITY.

At the close of Mr. White's paper the President introduced Mr. W. E. Gump, of the Writing Telegraph Company, of New York, who read a paper on "Transmitting Handwriting by Electricity."

Mr. GUMP said: The art of telegraphing letters or character while forming them with a pen or pencil, with connections to a tran mitter, so that they are reproduced in fac-simile by a receiving pe was first invented by Mr. Edward Alfred Cowper, of Westminst

England, and was justly considered a brilliant telegraphic marvel. The principle which guided Mr. Cowper in the invention was the familiar law of resultant motion when two opposing forces are combined. It must be observed that the action of a pen or pencil in writing is twofold. There is the "up-and-down" stroke, and the "right-and-left" movement of the pen along the paper, the curved letters being the resultant of these two motions.

The art of writing by telegraph, therefore, consists in suitable apparatus for transferring over wires these two opposing forces, and recomposing them into a resultant motion that shall exactly resemble the original movement.

To accomplish this Mr. Cowper employed two separate telegraphic circuits, each with its own wire, battery, transmitting and receiving apparatus. One of these circuits he made to transmit the up-and-down component of the pen's motion, while the other simultaneously transmitted the right-and-left component. Each continuously varying component was transmitted by causing the resistance of the circuit to vary with the component in question. At the receiving station these two components were recomposed by a pantograph arrangement of taut cords, and the resultant motion was thus communicated to the duplicate pen.

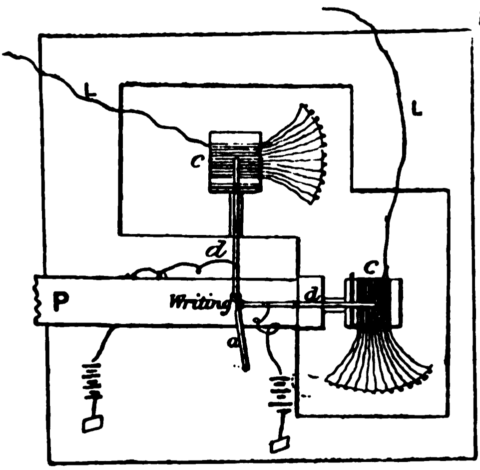


Fig. 1.

The transmitting apparatus is shown in figure 1.

The pen or pencil, *a*, is held in the writer's hand in the ordinary way, and to it are attached two arms, *d d*, one for each circuit. The paper, *p*, is moved underneath the pen by clockwork. The arms, *d d*, are insulated from each other, and each connected to its particular battery, the other pole of said battery being connected to earth. At the free extremity of each arm a sliding contact is fitted,

and as the pen, *a*, is moved in writing, these contacts slide lengthwise across the edges of two series of thin metal contact plates, *c c*, insulated from each other by paraffined paper. There are thirty-three plates in each series, and connected between each pair of these plates there is a resistance coil of German-silver wire, and the last of these is connected through the last plate to the line wire. It will be seen that as the pen is moved in writing the rods pull the sliding contacts to and fro; and as they slide over the contact plates they cut out a greater or less number of the resistance coils, proportional to its motion, and thus continually vary the electrical resistance in the line wires. The up-and-down movement varies the resistance in that line, and the right-and-left the other; and as the movement of the pen in forming a curve is the resultant of two motions, each motion is given to the line in its exact proportion.

The plan of the receiving instrument is shown in figure 2. Light pivoted needles, *h h*, are surrounded by coils of fine insulated copper

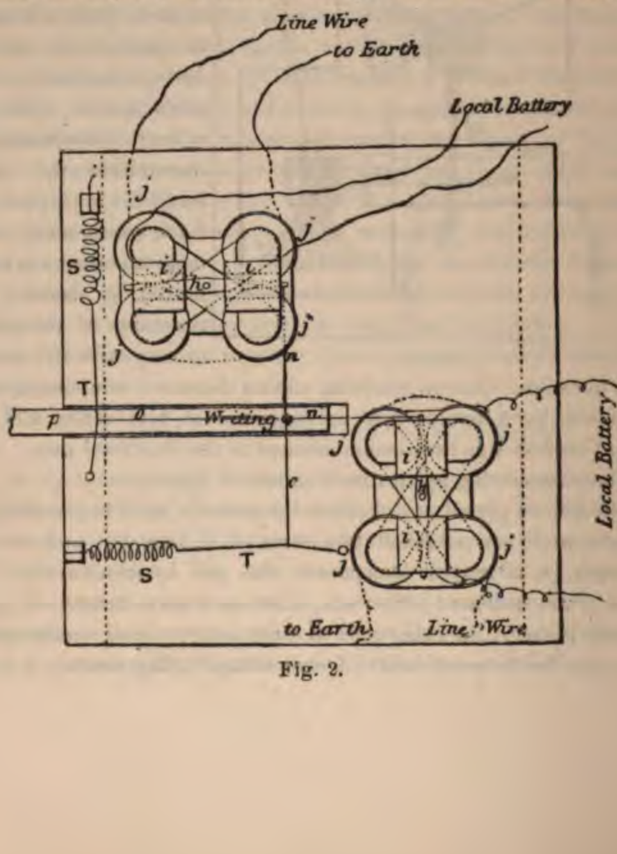


Fig. 2.

wire, *i i*, and controlled in their zero position by the electro-magnets, *j j j j*, placed underneath. The line wires pass through the coils, *i i*, to earth. Attached to the point of each needle is a delicate cord. These cords, *n n*, cross each other, and are kept taut by the threads, *o o*, and by the springs, *s s*. The springs exactly balance the strain on the cords from the needles, as long as the resistance in the line is constant, and the needles remain at rest. Where the cords, *n n*, cross, they are connected to a glass siphon pen, which is suspended by a thread, and free to move in any direction.

Now, since the needles deflect in proportion to the strength of the current flowing through its coil, the points of these two needles keep moving with the varying currents sent into the lines by the transmitting pen, and pull the receiving pen in two directions at the same time; and as it cannot follow both motions, it takes a path between them, that is the result of the two forces, and reproduces the original curve made by the transmitting pen.

This was the first telegraph which could really be called autographic. The writing over a circuit of forty miles was very distinct and a fair reproduction. There was a tremor in the writing by the receiving pen, but nothing objectionable.

Mr. J. Hart Robertson was the second inventor in this line of telegraphy, but was, however, unaware of the achievements of Mr. Cowper for some time.

Mr. Gump next described the various steps taken by Messrs. Cowper and Robertson in their efforts to produce a perfect machine, drawings of the different transmitters and receivers being shown upon the screen. The speaker then continued: The transmitter to be exhibited this evening has two series of about thirty carbon disks in each, placed at right angles to each other in a hard-rubber receptacle. Each disk was one-half inch in diameter, and one-fortieth of an inch thick. The normal pressure of each series of disks is adjusted by a screw. The stylus rod has insulated pressure points opposite the piles of disks, and is supported at the base on this spring wire, so that the rod can be manipulated as in writing, and in so doing the pressure points are pressed against springs which press upon the carbon disks, and thus vary the current. It takes the most minute pressure to make a great variation in the resistance, and for this reason the transmitter is placed six inches below where you take hold of the handle to write.

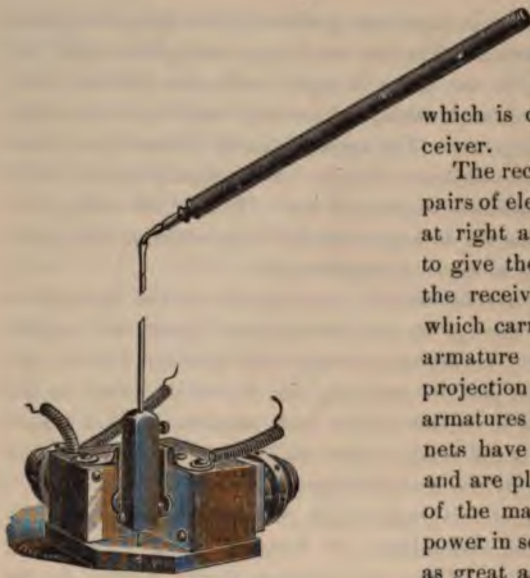


Fig. 3.

Each series of disks is in circuit with one of the line wires which is connected to the receiver.

The receiver consists of two pairs of electro-magnets placed at right angles to each other, to give the two movements to the receiving pen. The rod which carries the pen and the armature has a spring wire projection at its base. The armatures for each pair of magnets have a brass connection, and are placed above the cores of the magnets. The loss of power in so placing them is not as great as was expected, and the advantage gained is a nice movement of the pen. The armature rod carries the inverted thimble, which floats in a cup of glycerine, through which the armature rod projects. The transmitter and receiver are placed in a case, which also contains the mechanism for moving the paper. Above the case projects the handle of the transmitting stylus and the armature rod, carrying the pen.

Fig. 4.

The manner of writing is by watching the receiving pen and moving the stylus to make the pen form the characters desired. A movement of the stylus rod to the right brings a pressure on the right-and-left series of carbon disks, which sends a current into the right-and-left receiver magnets, which, attract-

Fig. 5.

SAMPLE OF WRITING IS SHOWN IN FIGURE 6.

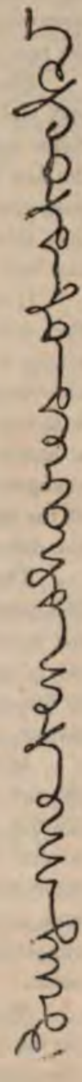


Fig. 6.

ing its armature, pulls the pen in that direction. In the same way a downward pull of the transmitter stylus gives a downward motion to the pen, and the other movements are the resultant of these two.

The pen being placed in an opposite position to the customary one, and the paper moving to the left, instead of the hand to the right, makes it seem very awkward and difficult to learn to write for the first five minutes, but during the next few minutes the learner sees what is required, and soon writes legibly. In very few cases does this require a half hour's practice, the majority learning it in one half of that time.

It is not an exaggeration to state that they soon find it easier than writing direct on paper. It has its advantages, too, in the simplicity of the instrument necessary for the work. By pulling the pen electrically, by means of the stylus, the writer is not aware that he is at one time exerting a greater pressure upon the carbon disks than at another to form the same letter, and in this way overcoming any changes of resistance in the line or battery, because the movement of the stylus rod where it presses upon the disks is always so small the difference is not discovered.

The characteristics of the handwriting of the operator all appear. If a person writes with a regular rolling hand, he will not be limited for speed. The young men in our New York office easily write thirty words a minute. Others make all the letters of the alphabet in fifteen seconds. Both receivers being adjusted to the same transmitter, the same writing is reproduced on each.

It has been the aim of our company to first perfect what it considered the most simple and practical instrument for commercial use. To this end we have operated them in a small way commercially in several towns during the past year, and had experienced men watch their working in order to thoroughly adapt them for the work which was expected from them. The experience was valuable, and the simple changes required will give us a thoroughly commercial instrument.

We are often asked what effect has induction on the writing. So far we have never noticed any whatever. They were tried with the electric wires in subways in London, but the induction was not apparent in the movement of the pen.

At Pittsburg we use poles in conjunction with the electric light

company, and run bare wires among theirs for distances of a mile or more, without the slightest disturbance to the moving pen.

At the close of Mr. Gump's paper numerous questions were asked and answered, after which the meeting was adjourned to enable the persons present to examine the instruments in operation, and also the watchman's clock. Samples of writing transmitted from one part of the room to the other were given to many of those present.

MEETING 379.

The Phonograph and the Phonograph-Graphophone.

BY PROF. H. W. VAUGHAN.

The 379th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, November 8th, at 8 P. M., Prof. C. R. Cross in the chair.

The records of the previous meeting were read and approved.

The chairman then announced the subject of the evening to be a description and exhibition of the Phonograph and the Phonograph-Graphophone,— inventions of Edison, Bell, and Tainter. He then explained the acoustic principles involved in the operation of the machines, illustrating his remarks by experiments with tuning forks, organ pipes, etc.

After this explanation the chairman introduced Prof. H. W. VAUGHAN, of New York, who briefly described the principal features of the machines, and indicated some of the uses to which they could be put.

At the close of Prof. Vaughan's remarks a vote of thanks was passed to the speaker for the exhibition. The meeting was then adjourned to give the persons present an opportunity to personally inspect and listen to the machines in operation.

MEETING 380.

The Summer School of Mines.

BY PROFS. R. H. RICHARDS AND F. W. CLARK.

The Summer Course in Topography, Geology, and Geodesy.

BY PROFS. A. E. BURTON AND G. F. SWAIN.

The 380th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, November 22d, at 8 P. M., Prof. G. F. Swain in the chair.

After the reading of the records of the previous meeting, and the election of new members, the chairman introduced Prof. R. H. Richards, of the Institute, who gave an account of the Summer Schools of Mines.

Prof. RICHARDS said: The Summer School of Mines of 1888 was of a character entirely new to our Institute, although it has been adopted by Columbia School of Mines, and Washington University, for some years, namely, to locate in one spot and to go to work.

The spot chosen by us was the Eustis mine, of Capelton, near Sherbrooke, Canada, a pyrites mine carrying copper.

After providing ourselves with tents and food, we next laid out our work, and it was divided into two classes, one above ground and one under ground. The latter will be described presently by Prof. Clark. Parties were formed of four students each. Two parties worked on the surface and two under ground. This work continued four days, at the end of which time the parties exchanged places.

The work on the surface consisted in examining and describing the methods of sorting and shipping the ore, in making assays of some of the products, and in making a geological survey of the neighborhood. In this survey some two or three hundred outcrops of the ledge were visited, located, and plotted on a map. At the close of the geological work a somewhat novel survey was made. After

determining some hundred or more dips and strikes over a considerable area, to get a reliable average, and assuming that the dip and strike of the copper vein was the same as that of the rock, we made a diagram which gave us the rise or fall of the copper vein at all points of the compass. We then, while running the line, and in selecting each new direction, had only to point the compass in such a direction that the rise or fall of the ground would be the same as the rise or fall of the vein for that bearing. Then, provided our premises were correct, we could follow this line with confidence that we were on the outcrop of the copper vein, even though no surface indication whatever could be found. In this way a line about half a mile long was run through thick forest along the supposed outcrop of the vein. We found little in the way of surface indications on this line until we came to the end of it, where we found a group of costeaning ditches and prospecting pits, which indicated that they belonged to the same copper vein as the mine. Prof. Richards gave some interesting accounts of their camp life. He also expressed himself as being perfectly satisfied that the experience gained by the students was of great benefit to them.

At the close of Prof. Richards's remarks the chairman introduced Prof. F. W. Clark, who gave an account of the under-ground work of the school.

Prof. CLARK said: The under-ground work was divided as follows,— each squad worked four days on mine survey, four days on drilling and blasting, two days on timbering, and a day each on track and cars, engine and ropes, and rock drills. After the work common to all was finished, those who chose to do more work of this character located two or three points in the mine on the surface, and several vertical shafts for the future working of the deposit, did additional timbering and other mine work, examined and reported on neighboring mines and works, made a section on the line of two of the slope shafts, etc.

As will be seen by the plan and section of the mine maps, the workings are very irregular and slope at an angle of 35°, but vary from 15° to 70° in different parts of the mines. The deposit varies in thickness from four feet to nearly sixty feet. The roof or hanging wall is supported by timbering and heavy pillars of ore, so that the mine is a very open one. Great trouble was experienced in holding

stations in many parts of the mine, owing to the great hight of roof and the filling or loose ground under foot. Spikes on studs, drill holes, stake and clay spots on roof were generally used for survey stations. The first survey squad established a base line on surface outside of adit, brought the line in about 1000 feet to slope shafts, then descended on the line of No. 3 shaft, crossed over to ladder way on the opposite of mine, and ascended to starting point. The next squad began at the two lowest stations, and surveyed another loop, finishing at their starting point, etc. Both horizontal and vertical angles were always read, the distance measured in the line of sight, and the horizontal and vertical distances calculated and plotted. If any errors in measurement or calculations were made, the work would not check, and had to be repeated.

The drilling was done in squads of two, one man holding and the other striking. Men selected by the superintendent of the mines instructed the students in the details of the work.

The timbering was done in the same manner, the students helping to take the measure for the timbers, cutting the britches, framing the timbers, and putting them in place with the timber gang.

The boys were very green at first, and amused the old miners very much; but in a week they were perfectly at home, and went about the mine with the assurance of old hands, in striking contrast to their first visit under ground. Every one, from the superintendent down, did everything he could to make the visit pleasant, and I think all the miners were sorry when we left.

No accidents of consequence occurred under ground. A few bruised hands and limbs, when drilling, and a few slips while surveying, make the sum total of accidents.

THE SUMMER COURSE IN TOPOGRAPHY, GEOLOGY, AND GEODESY.

The chairman then introduced Prof. A. E. Burton, who gave a brief account of the work of the Summer Course in Topography, Geology, and Geodesy.

Prof. BURTON said: The subject of a Summer School of Topography, Geology, and Geodesy was first discussed at the Institute of Technology about two years ago, and during the winter of 1887 a definite programme of work was arranged, and the course was made an essential part of the geodetic option in the Civil Engineering

Department. It was also decided to allow all third-year students at the Institute, who were properly qualified, to attend this school without the payment of extra tuition; and applicants, not students of the Institute, were to be admitted after passing a satisfactory examination, on the payment of a fee of twenty-five dollars.

There is a growing demand in this country for good topographers; and it is a fact that our general and State governments, in prosecuting topographical surveys, have found it difficult to obtain from engineering schools skilled assistants in this branch of work, the greater demand for constructing and railroad engineers having forced the subject of topographical surveying into the background. It was in some degree to meet this demand that the present school was planned.

Columbia College, New York city, has for some time past maintained a summer school of geodesy, and summer courses, in general field work, have from time to time formed part of the course of engineering instruction in other scientific schools; but there are some individual features about our own course that may warrant special mention.

Reference is here made to the fact that especial attention has been given to methods of repesenting the actual relief and contour of the ground, and to the elucidation of the intimate connection between topographical phenomena and the underlying geological structure.

To best convey an idea of the aim and purpose of this school, a short account will be given of the work done during the month of June, 1888, at South Deerfield, Mass.

South Deerfield, on the Connecticut River, had been chosen as the field of operations for several distinct reasons.

First, there were the interesting topographical and geological phenomena presented by Sugar-Loaf Mountain, and the fine terraces of the Deerfield and Connecticut Rivers.

Second, there were the superior facilities offered for base-line measurement and the connecting triangulation.

Third, there were the many railroad lines, offering every facility for excursions to adjoining territory.

Fourth, there was the excellent opportunity offered for conducting the hydraulic measurements, offered by the long straight reach of the Connecticut River at this point.

The corps of instructors consisted of Prof. Niles, Prof. Swain, Assistant-Prof. Porter, and myself.

On the first of June eight third-year students presented themselves as members of the School, and of these two were students taking the geodetic option. The party arrived at South Deerfield on the afternoon of June 1st, and took up their quarters at the Bloody-Brook House. Work began promptly the next day, and consisted first of experiments with the various hypsometric instruments, *i. e.*, a mercurial cistern barometer (Green), one Cassella hypsometer or boiling-point thermometer, one Pitkin aneroid, one Green aneroid, two small Cassella aneroids, one Goldschmidt aneroid. These experiments were continued for several days, until all the students were familiar with the reading and manipulation of the different instruments. Sugar-Loaf Mountain furnished an unusually good field for these experiments, on account of its abrupt ascent from the plane of the valley, and also on account of the subsequent verification of its hight by trigonometric and spirit-levelling. Mount Toby, having an altitude of 1275 feet, furnished a point for a single series of comparisons of the various instruments.

After this work, on which the whole class were engaged at one time, the party was divided into two divisions, one division taking up the geological and topographical field work, under the direction of Prof. Niles and myself, and the other taking up the measurement of the base line and the construction of a profile across the valley, through Sugar-Loaf Mountain, under the direction of Assistant-Prof. Porter. By dividing up the parties in this way, and alternating their days of work, the instruction was made more individual than it could have been if all had been engaged on the same piece of work at the same time.

The base line was measured along the line of the Connecticut River Railroad with a steel-wire tape three hundred feet long, suspended at the ends and at two intermediate points. The measurement was carried on over a distance of 5400 feet. The positions of the ends of the tape were marked by lines scratched on a zinc plate fastened to the head of a light tripod. The intermediate supports were hooks hanging from a ring attached to the head of a light tripod. In order to keep the length of the tape as near to the standard length as possible, and to know its variation at any given time

from this standard, it was necessary first to determine the number of pounds of pull necessary to stretch the tape enough to make up for the shortening due to sag. Secondly, to determine the changes of length due to changes of temperature, and, thirdly, to make allowance for these changes in connection with amount of pull.

The determination of the modulus of elasticity of the tape, and the shortening due to sag and the co-efficient of expansion, were all matters of field work and computation on the spot. The steady pull necessary for accurate work was attained by attaching the end of the tape to a hand-screw held against a heavy stake driven firmly into the ground. The amount of pull was measured by a spring-balance, the variations of which, from a standard, were subsequently determined in the physical laboratory.

The profile across the valley was a combination of spirit-leveling, stadia work, and trigonometric leveling from base lines, and brought out many interesting and novel problems arising principally from the natural difficulties of working on the nearly vertical slopes of Sugar-Loaf Mountain.

Trigonometric leveling from the long base line to the summit of Sugar-Loaf and from two shorter base lines agreed within a fractional part of a foot.

This elevation, determined by these different independent measurements, furnished a standard of comparison for the results obtained by the hypsometric instruments referred to previously.

The astronomical work was very slight, owing in great part to the lack of preparation of the students for this kind of work.

The topographical work, proper, was carried on exclusively by plane table methods. For this work a region was first selected possessing a somewhat complicated and irregular contour, and each student was furnished with a small rude sort of plane table and a compass sight alidade. A base line of some 700 or 800 feet was quickly measured and plotted on each one of the plane table sheets. Each student then carried on an independent graphical triangulation over the area selected for study, using, as far as possible, natural objects for signals. When this triangulation work had been finished and tested, the next step was the sketching in of the configuration of the surface of the ground by a system of line shading, these lines being drawn always in the direction of contour lines, and indicating, by their spac-

ing and the resulting effects of light and shade, the different degrees of slope. After some practice in the field a student became able to present, by these lines, a very fair and intelligible idea of the actual modeling of the ground on which he stood. The plane table sheet at this stage showed a surface covered with light lines, all taking the direction of actual contour lines, but no line representing any known elevation. Next followed the selection from these lines of five-feet contours, elevations being determined for this purpose with the clinometer and hand level; and as all the different sheets used the same base line and same datum plane, they could all be brought together and a comparison and combination of results made.

These maps, resulting from this sketching method, were taken into the field and criticised by the instructor, and attention was particularly called to the geological structure, and to the causes which had produced the actual forms as they had been mapped. This study usually led at once to a more intelligent and correct drawing of the contour lines. These lines were no longer to him simply irregular curves, but all these bends and turns had a meaning, and were seen to tell the life story of the ground.

All this mapping with crude instruments is simply preliminary training to the construction of a map with the most approved appliances.

A typical piece of ground, representing strongly one simple topographical feature, was selected,—an old river terrace, at the present time deeply furrowed by the drainage from the hillside above. A map was here constructed according to the most approved methods of plane tabling on large scale work, the stadia being used in connection with the telescopic alidade for obtaining the detail of the ground, both horizontally and vertically. In this work the student was fully aware of the cause of the phenomena before him, and had in his hands instruments for precise measurement, and here was his opportunity to show the benefit of all the previous instruction.

The maps finished during the month were insignificant when actual areas were considered, but as typical representation of topographical phenomena they were very interesting.

Geological field work was not confined to the discussion of the features included in the maps, but excursions were taken in different directions to illustrate characteristic points.

At the close of Prof. Burton's remarks the chairman gave an account of the work in hydraulics done in connection with this course.

Prof. SWAIN said: The hydraulic work was executed during the last week, and consisted in measuring the flow of the Connecticut River by various methods. Two parallel lines, 350 feet long, were measured off, one on each bank of the river, and stakes driven every 50 feet. Two gauges were established for reference. The stream was then cross-sectioned, at each station soundings being taken every 50 feet across the river (which was about 1000 feet wide), giving therefore eight cross sections at equal intervals of 50 feet apart. The average depth of the stream, for the entire distance of 350 feet, was then computed at short intervals across, and the average cross section plotted, and this average cross section was used in the computation of the discharge from the float measurements.

These float measurements were made by the use of double floats of tin, of the kind used by Gen. Ellis in his measurements on the same river. It was designed to obtain with these floats the velocity of the stream at equidistant intervals of 50 feet across the river, three floats being sent out from each point, one of which was placed with the lower float about at mid depth (of the average depth), while another was arranged with the lower float close to the surface, and a third with the lower float close to the bottom, or as close as it could be without touching during its passage from transit line to transit line. Transits were set up on the west bank, 350 feet apart, that is, at the upper and lower transit lines. Floats were sent out from points above the upper line. The time which they took in passing through the distance of 350 feet was measured by the stop watch, and the distance out from the bank, at the upper and lower transits, was determined by sighting on them from the instruments at the instant when they crossed the lines. The observations taken by this method were plotted, and the quantity discharged by the stream determined by various methods.

Measurements were also made with the current meter, two kinds of instruments being used, namely, the form used by Fteley and Stearns, in which the meter has to be raised to the surface in order to count the number of revolutions; and the electrical meter, used by Gen. Ellis, in which the number of revolutions is recorded by electricity by a counter

in the boat, without raising the meter out of the water. With both of these instruments the discharge of the stream was measured at one of the cross section lines. The measurements were made in various ways. Sometimes the average velocity in a vertical was determined by using the instrument uniformly from top to bottom, and back several times. In other cases the velocity was determined at certain points in the cross section, at different depths and at different distances from the banks. All these measurements were plotted and the discharge of the stream deduced from them.

The results of the work were very satisfactory, and the students obtained a good knowledge of the methods employed. The actual quantities deduced were not, however, of much practical value, and could not be easily compared with one another, for the reason that during the time of the measurements the stream was unfortunately rapidly changing its level in consequence of severe and sudden rains which had occurred over certain parts of its basin. During the first part of the measurements the river was rising at a rapid rate, while during the last part it was falling equally rapidly. It is unnecessary to say that under such circumstances any measurement of flow is more likely to be in error, and is of less value than if taken while the river is at a uniform state. The object in this case, however, was not to find how much water was flowing in the river, but to teach the students how to measure the flow of the stream, and this was accomplished satisfactorily.

MEETING 381.

Peculiar Rotary Motions found in Lightning and other Electrical Currents.

BY MOSES GREELY PARKER, M. D.

The 381st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, December 13th, at 8 P. M., Hon. J. A. Dresser in the chair.

After the reading of the records of the previous meeting, the chairman introduced Dr. Moses G. Parker, of Lowell, who read a paper on "Peculiar Rotary Motions found in Lightning and other Electrical Currents."

Dr. PARKER said: Photographing lightning and making good pictures, representing the forked and irregular light as it shoots across the sky, or from cloud to earth, has become quite common, and is easily done on a dark night; having first focussed the lens for distant objects, one has only to point it in the direction he expects the flash to appear, expose the plate, and wait for the lightning. If the night is dark, one can obtain several flashes of lightning on the same plate, as they often occur near together. The only difficulty is to have the flash come within the field of the lens.

Photographing the current itself so as to get detail in the track, showing how the electrical currents travel, is quite another thing. This we have been able to do, and present some results, as seen in figures 1, 2, 3, and 4.

From these we see that the electrical current may travel without dividing, or it may divide and sub-divide, twist and meander in its passage from cloud to earth, its image on the negative presenting such a variety in form that many names have been given descriptive of its general appearance, without any reference to the real motion of the current itself.

Three of these motions I have observed, viz., the twisted, the curled, and the straightforward.

The twisted motion, as seen in figures 1, 3, and 4, resembles a loosely-twisted rope. It twists both ways, usually from left to right,

Fig. 1. Reproduced from photograph, showing the attraction and repulsion of the currents, also the rope-like twist.

as the twining vine winds around its support. There are exceptions to this rule in the electrical as well as the vegetable kingdom, for we find it twisting not only both ways (*i. e.*, from left to right, and right to left), but it reverses its motion in the same course.

The curled motion seen in figure 2 resembles a twisted ribbon or shaving as it curls from the carpenter's plane, and in some respects is most remarkable.

Fig. 2. Reproduced from photograph. Ribbon Lightning, showing its curled motion.

The straight presents straight lines in its track, and is evidently traveling with great force.

[The Doctor here made quotations from the report of the Committee of the Royal Meteorological Society of London, issued last year, which classifies lightning under six different names, viz., stream, sinuous, ramified, meandering, beaded, and ribbon lightning.]

Some two years ago, while experimenting with electricity, I obtained a photograph showing the dividing and twisting rotary motion of the electrical current, as seen in figure 1. My plate was not quite in focus, but the image is sufficiently sharp to show that the current divides and rotates, not only on itself, but upon its fellow.

Knowing, as we do now, that the current has a rotary motion, we can see, in the main track, indications of this motion, that would be impossible for any jarring of the camera to produce. Further investigation disclosed the three motions before mentioned, to illustrate which I have, by permission of A. H. Binden, taken figures 3 and 4 from his remarkable photographs of many flashes of lightning, about which, it was truly said in the *Boston Herald* of July 29, 1888, "Mr. Binden has been singularly fortunate in securing, with his two plates, photographic reproduction of all the typical forms of lightning flashes mentioned in the committee's report."

The lightning flash, examined as a whole, is seen to leave the cloud and reach the earth in an irregular, twisting, rotary manner, throwing off branches as it goes; these also twisting, rotating,

Beaded, Meandering, Sinuous and Ramified Lightning.

Fig. 3. Reproduced from photograph, showing rotary mot on.

and sub-dividing into the sinuous, ramified, meandering, beaded or chapleated, and ribbon lightning, mentioned in the Royal Society's report, while the main current, rotating as it goes, finally enters the earth in a divided form, as seen in figures 3 and 4, which plainly shows this twisting rotary motion in the main current as well as in its branches.

Stream lightning is well described by its name alone. In this form I find what I have called the straightforward motion, — its photographs show almost straight lines without the curves indicating the rotary motion.

Sinuous, ramified, and meandering lightning, figures 3 and 4, are all very much alike, if we grant that which we can hardly doubt, viz., that they all may divide and sub-divide as they advance. In all of these we find a rotary motion, with a direction either from left to right, or right to left; in some branches both motions are found, and when well defined, resemble the twist of a rope.

Beaded lightning, seen in the end of figure 3, has that about it that is much more interesting from a speculative point than either of

the others. The explanation given in the Royal Meteorological Society's report of the beaded form barely explains all that we find in and on both sides of this bead, for we see the rotary motion of this current before entering the bead to be in one direction, and immediately after leaving the bead to be in the opposite direction, plainly indicating that the motion sometimes changes in the bead.

Ribbon lightning, as seen in figure 2, has what I have designated the curled motion. In this one sees the resemblance to a curled ribbon. This current is evidently flat, with a motion that forms this ribbon into a curl, as seen at the end. It somewhat resembles the beaded form, inasmuch as it is seen to change its direction, thus

Fig. 4. Photographic view of ramified and meandering lightning, with loops and rotary motion.

forming curls twisted in opposite directions, and united, not by a bead, as in the beaded lightning, but by a white edge where the process of reversing its motion goes on, as seen near the center, while near the end it presents the appearance of a curl pulled sidewise, being thin and narrow,— afterwards proceeding in a more regular manner than before. No possible shaking of the camera could produce this curled appearance.

That currents of electricity are influenced by the medium through or upon which they travel is seen in figures 3 and 4, and to the well-known theory that the resistance of the air changes its direction may be added that the current changes in size and contracts in volume as it enters the earth, as seen in figure 3.

If we compare the size of these currents with the trees or other known objects, seen in the same photograph, taking into consideration the distance each one is from the lens, one must, by comparison, judge the size of large currents to be, while passing through the air, *several feet* in diameter. Distance must always be considered in judging the size, for as the current goes from the lens its image on the negative gets smaller, and larger as it approaches it.

Sparks from an induction coil or Holtz and other machines give the same indications of the three motions found in the lightning. They are easily photographed. The variety is not so great as in lightning, but one has an opportunity here of varying the current in many ways.

The three motions, the reversing of the rotary motion in the continuous track of a spark, as well as the bead, are found in these currents as in lightning, and adds proof that these and lightning currents are similar.

A large number of photographs of lightning and artificial currents were thrown upon the screen, and minutely described by the lecturer. He called attention to some flashes which approached and receded from each other, like the contour lines of a vase. This, he thought, could be explained by a theory of attraction and repulsion; and in referring to one case, where several flashes occurred on the same plate, he thought that it was not only possible to point out, by this theory, the flashes that came simultaneously, but also to show, by the theory of rotation, what he supposed to be the return current, as he finds the

rotary motion in this current to be in the opposite direction from that found in the main current.

After some discussion, the meeting closed with a vote of thanks to the speaker for his interesting paper.

MEETING 382.

Recent Studies in Telephony prosecuted in the Rogers Laboratory of Physics.

BY PROF. CHARLES R. CROSS.

The 382nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 10th, at 8 P.M., Hon. J. A. Dresser in the chair.

After the reading of the records of the previous meeting the chairman introduced Prof. Charles R. Cross, of the Institute, who gave an account of "Recent Studies in Telephony prosecuted in the Rogers Laboratory of Physics."

Prof. CROSS first gave a brief account of the earlier work done in this line. He then said: In the spring of 1887 Messrs. G. W. Patterson, Jr., and H. J. Tucker experimented on the contact in the Blake microphone transmitter, with the object of determining, if possible, the relation between the normal pressure at the contact, and the current in the receiver of the telephone, which was placed in the secondary circuit of an induction coil in the usual manner.

The object of the work being to determine the variations in the secondary undulatory current caused by variations in the normal pressure at the microphone contact, some simple way of regulating the contact pressure was required,— some way, if possible, which would admit of reproducing precisely the same results from the same conditions of pressure and sound. This latter was not accomplished satisfactorily.

Having removed the door, including the microphone contact and the mouth-piece, from the transmitter, it was fastened to the table, leaving space between it and the table for an organ pipe (512 complete vibrations per second), which was used as the source of sound.

To obtain a sound of constant intensity the pipe was blown by means of an air blast driven by the engine in the Rogers Building. The air was regulated by two pressure regulators, one allowing part of the air to escape, the other balancing the air pressure by a column of mercury. The hight of the mercury could be changed at will.

The pressure in the Blake contact is regulated by the attachment of the carbon electrode to a spring, whose tension is adjusted by a screw. In addition to the spring, which was used for preliminary adjustment, pressure was applied by means of a lever arm carrying a scale-pan at its center, one end of which rested on the electrode; the other, carrying a knife-edge resting on glass, acted as a fulcrum. The scale-pan was covered by a piece of velvet, in order that the addition of weights might cause no jar at the contact. In the experiments it was found that any attempt to take off weights had the effect of disturbing the adjustment of the contact to such an extent as to break the series. This same result was frequently brought about by the jarring of the ground from the street traffic.

A more powerful induction coil was used than that in the Blake transmitter. The resistance of its primary was 0.5 ohm, and of its secondary, 899 ohms.

Various forms of battery were experimented on, with varying arrangements of the cells, to observe the effect of changes in electromotive force and in resistance. The currents to be measured were very small, and consequently some extremely sensitive form of electro-dynamometer was required. One of the Kohlrausch pattern, with movable coils, was used, which was wound with No. 40 (B. and S. gauge) double silk-covered wire. The two outer coils might be used either in parallel or in series with each other, and in either way with the inner (suspended) coil.

This dynamometer, which differed in some of its details from the instrument as ordinarily made by Hartmann, was constructed especially for experiments of this nature by Mr. Otto Scholl, the mechanician of the Laboratory.

Having completed the necessary apparatus, they proceeded to

investigate the law of relation between pressure and current, using the Dolbear and chromic acid primary batteries, and the Brush storage battery.

The pressure at the contact was adjusted by the spring until the addition of 25 mgr. would allow sound to be transmitted through the telephone; the weight was then increased, at first by additions of 250 or 500 mgr., and afterward more rapidly.* The deflections, the quality, and the intensity of the sound transmitted were noted.

The values given in Table I are those of the steady currents, which, in the absence of any magnetic effects from the earth, would give the deflections observed. As the precise form of the variation of the current is uncertain, no better mode of procedure has suggested itself. The columns headed Def., C., and Wt. contain the observed deflections, the calculated currents, and the weights in the pan. These weights should be divided by 2 to obtain the pressure at the contact.

Table I.

BRUSH STORAGE BATTERY, TWO CELLS IN PARALLEL.

1.				2			
Def.	C.	Wt.	Remarks.	Def.	C.	Wt.	Remarks.
.85	.34	0	Broken sound.	2.20	.54	0	Roaring.
3.05	.64	250		4.05	.74	250	Bad.
5.30	.84	500	Loud, and beginning to be musical.	4.30	.76	500	
6.45	.93	750	Loud and good.	2.10	.53	750	Loud, and beginning to be good.
4.35	.76	1,000	Lower, and clear.	2.05	.52	1,000	
3.95	.73	1,500	Wavy.	.65	.29	3,000	Loud and good.
2.55	.59	2,000	Good.	.65	.29	4,000	Good, but growing fainter.
1.75	.68	2,500		.45	.25	5,000	
1.10	.39	3,500	Low.				
.32	.20	4,500	Very low.				

It will be noticed that the current rises very rapidly at first with this increase of pressure. At all points of this rapid rise the sound transmitted is very bad, and there are very frequent breaks with the intensity of sound employed. The maximum is soon reached, at about 1000 mgr. pressure, and from that point the current falls off gradually. The sound becomes good soon after the maximum current is reached, and as the pressure increases the sound diminishes in

* In some series the increment was only 25 mgr.

intensity but improves in quality. In all our experiments the same form of curve represented the variation of pressure and current, and in all the best sound was transmitted directly after the maximum current.

In experimenting with electro-motive forces greater than 3 volts we met with unsatisfactory results. Good sound was not transmitted except under heavy pressure, and all attempts to obtain satisfactory measurements failed on account of the well-known disturbances set up in the microphone by the current itself.

In certain of their experiments the resistance of the primary circuit was diminished by joining a number of cells in parallel. The uniform result was that the sound transmitted was louder.

The results of the experiments may be summed up as follows: —

The resistance of the primary circuit, and especially that of the battery, should be as low as possible; the pressure at the contact should be no greater than is required to transmit good sound,— that is, it should be a little greater than that required to give the maximum current; with the present form of Blake contact, no electromotive force greater than 2 volts should be used; and, finally, the contact should be carefully guarded against jarring.

The following spring Miss Annie W. Sabine undertook a study of the variation of the current in the secondary circuit of a microphone transmitter, as related to variations in the normal pressure and in the mass of the electrodes of the microphone. This forms a continuation of the work just described.

The instruments used were similar to those previously employed by Messrs. Patterson and Tucker.

The microphone contact was set into vibration by the sound of a stopped organ-pipe (C_4 of 512 vibrations), kept as constant as possible by means of an air-blast furnished with a regulating air-chamber. Weights were gradually added to the upper (anvil) electrode, so that the mass of this and its pressure on the lower electrode were thereby increased by measured amounts. The weights added were usually in the form of thin copper washers, weighing $\frac{8}{10}$ of a gram each, though fractions of this weight were used in some cases. One chromic acid cell was used as a battery.

The character of the results obtained will be found in Table II, which, when plotted with the abscissas representing the normal press-

ures, *i. e.*, the added weights, and the ordinates the currents produced in the secondary, gives a curve showing the relation between the normal pressure and the resulting current, with electrodes of the materials employed in the Blake transmitter, viz., a platinum hammer and a hard carbon anvil electrode. The load is given in terms of the arbitrary unit employed; the currents are given in milliampères.

Table II.

Load.	Current.	Remarks.
0	0	
.5	.18	
1.0	.46	Loud, good quality, fluttering.
1.5	.48	" " " "
2.5	.56	" " " "
3.0	.49	
3.5	.45	Faint, good quality.
4.0	.33	" " "
4.5	.21	
5.0	.19	

The curve shows a rapid rise at first, as the mass of the anvil electrode, and with it the pressure between the electrodes, is increased, which rise soon reaches a maximum, the curve then falling off rapidly at first, more slowly afterwards.

The nature of the curve is interesting, and requires explanation. Mr. Patterson, who obtained similar results to Miss Sabine's, considers the curve to be composed of two separate branches, the rising portion of the curve corresponding to a motion of the electrodes sufficient to break the circuit, and the falling portion to the case when the pressure is too great to allow this to occur. The curve constructed upon this hypothesis greatly resembles one of his experimental curves. The sound in a receiving telephone placed in the secondary circuit is so harsh for this portion of the curve that one might well infer that actual breaks occurred; but this is very doubtful, and such breaking is certainly not essential to the production of the results which are obtained. In fact, Mr. Patterson assumes that the varying pressure on the contact due to the action of the given sound-waves will always have the same maximum value, $\pm\ \delta$. This would be approximately true were the normal pressure between the two electrodes

alone to be varied, but the effect of the addition of weights, as in the method of experiment adopted, is to increase the mass at the same time that the normal pressure is increased, and under these circumstances the effect of a sound-wave of given intensity will necessarily be to give to the corresponding pressure-variation a variable value, increasing with the added mass, and hence, with the form of apparatus used, as the normal pressure is greater. The effect of this will be to cause at first a gradual increase of current in the secondary, which increase is succeeded by a diminution of current when the mass is still further increased.

The momentary changes in pressure, Δp, $\Delta p'$, $\Delta p''$, etc., due to the sound-waves, and corresponding to loads and normal pressures p, p', p'', etc., have increasing values within certain working limits, owing to the increasing mass of the anvil electrode. The currents in the primary also increase, though at a gradually diminishing rate, as the pressure between the electrodes is increased, so that the increments of current, Δc, $\Delta c'$, $\Delta c''$, corresponding to the pressure-changes Δp, $\Delta p'$, $\Delta p''$, have increasing values up to some point, as a, after which they decrease. This being the case, it is evident that the current in the secondary will at first increase to a maximum, and afterwards diminish, since the currents in the secondary corresponding to pressures p, p', p'', etc., will be proportioned to Δc, $\Delta c'$, $\Delta c''$, etc., and this is precisely the curve which is obtained in the experiments. The explanation just offered seems therefore to be the true one.

The matter was still further tested by carrying out a set of experiments similar to those already described, except that the variations in normal pressure were brought about by means of a spring instead of by adding weights. In such a case the successive values of Δp, would be of the same magnitude, while Δc would continually diminish. The current in the secondary should therefore have its maximum value when the initial normal pressure is least, and continually diminish as that pressure becomes greater.

The experimental results verified this conclusion. The curve is approximately a straight line. It is possible that the deviations from this are due to instrumental imperfections, as the apparatus used did not allow of more than an approximate determination of the pressure applied by the spring.

The variations in the secondary current which occur under dif-

ferent circumstances as to mass and normal pressure when the material of the electrodes of the microphone is varied was next studied. The methods and apparatus employed were identical with those just described.

In the first series of experiments both electrodes were made of the same material, the hammer electrode being a very small button, and the anvil electrode a large one, as in the Blake transmitter. As the mass and pressure upon the anvil electrode were varied, the currents in the secondary at first increased up to a maximum, and afterwards diminished, as just described.

Comparing the results for carbon and platinum it was found that the maximum current obtained under the conditions of the experiment was about the same in both cases. But the current falls off far more rapidly with platinum as the pressure is further increased, thus giving to carbon a greater working range of pressure variation within which it can be practically used in a microphone transmitter, a fact long since recognized in practice. Iron has a considerable range, but the current produced is not great.

When the electrodes were of different materials, being made of the customary size, the hammer small and the anvil large, it was found that the character of the result obtained under these circumstances was determined chiefly by the material of the anvil rather than of the hammer electrode. This is particularly well illustrated in the case of iron and carbon. This difference persisted even when the hammer and anvil electrodes were made of the same size and shape. We have still to determine whether the same peculiarity would be observed with other modes of mounting the electrodes.

Besides the foregoing results, we have made a determination of the actual strength of the working currents employed on telephone lines. The values previously obtained in the Laboratory had been ascertained from experiments on very short experimental circuits. But through the courtesy of the Long Distance Telephone Company we were able to put our measuring apparatus in circuit both with the city telephone lines and with one of the long lines to New York.

Several interesting results were thus reached, as shown in Table III. The first column gives the name of the transmitter employed, the second the nature of the sound transmitted, the third the location of the transmitter, the fourth the strength of the telephone current in

milliampères. The length of the line from 95 Milk Street to the Institute was about two miles; that of the line to New York was two hundred and sixty miles.

Table III.

Transmitter.	Sound.	Locality of Transmitter.	Current.
Blake.	Talking.	95 Milk Street.	.185
"	Singing.	"	.52
Hunnings.	Talking.	"	.28
"	Singing.	"	.78
"	Talking.	New York.	.02
"	Counting.	"	.02—
"	Organ Pipe.	"	.01+
"	Counting.	Rogers Labroatory.	2.05
"	Talking.	"	2.20
"	Organ Pipe.	"	1.24

The speakers were Dr. W. W. Jacques, of Boston, and Mr. F. A. Pickernell, of New York, who kindly aided us in our work. They are both experts in the use of the telephone, and accustomed to work with each other. The pitch, as well as the loudness of the sounds used, was kept as nearly as possible the same. The vocal sounds transmitted were spoken in a very loud tone, and close to the transmitter.

The figures obtained with the long line to New York are very instructive, as they give some knowledge of the loss of current which is sustained in long distance telephony. When the transmitter was at the Institute, near to the dynamometer, the full current produced by the former passed through the latter instrument, while, when the transmitter in New York was the one used, it is clear that only what was left after all leakage, etc., passed through the measuring instrument. Assuming the sounds as produced at the two stations to be of approximately the same pitch and loudness, it appears that only about one one-hundredth of the original current produced at the transmitting station is finally utilized at the receiving station. It further appears from these figures that about 13 per cent of the current produced at the transmitting station was utilized in ordinary telephonic transmission over the local lines from 95 Milk Street to the Laboratory.

MEETING 383.

Cotton Culture in Central Asia.

BY MR. HENRY G. KITTREDGE.

The 383rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 24th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Mr. Henry G. Kittredge, of Boston, who read a paper on "Cotton Culture in Central Asia."

Mr. KITTREDGE said: The cotton supply of the world has become a question of serious moment. Notwithstanding the season of 1887–88 had the largest supply of cotton, with the exception of 1882–83, from which to make deliveries for the world's consumption, in the history of the cotton trade, it ended with only enough stock on hand to satisfy an average demand for three weeks and two days. The weekly average of cotton deliveries for consumption in the United States, Great Britain, and on the Continent, for this season, was 180,819 bales. There has been an almost steady yearly increase in the world's consumption of cotton since the war, or an increase since then of nearly 103 per cent. Within this period the cotton supply from the United States has increased over 203 per cent, while that from other sources has decreased nearly 33 per cent. The supply from all sources has increased nearly 67 per cent. With the consumption at an increase of 103 per cent, and the supply at an increase of only 67 per cent, it can be readily seen that the question of a cotton supply has already become a momentous one. It is noted that while there has been an increase in the supply from the United States there has been a decrease in the supply from other sources. Now it is clear either the cotton crops of the United States must be very materially increased or there must be very much larger productions from other cotton-growing countries. Preference at all times will be given to the cotton of our southern States, but there will come a time when cotton culture in the South will attain its fullest development. For the past number of years each season has increased its acreage from 2 to 5 per cent over that of the preceding

season. This cannot be expected to continue forever, and I do not think it too presumptuous to say that in all probability that development will be reached in the course of about twenty years, so that by 1910 the South will have attained the highest point in its cotton production. This means a crop of about thirteen and a half million bales. For the production of this quantity of cotton it would require 35,100,000 acres of land, yielding, on the average, 175 pounds of lint to the acre. This acreage is a little less than 8 per cent of the total area of the cotton States, and nearly 70 per cent of the tilled land enumerated in the census of 1880. With this acreage the larger part of the best land in the South, at present in suitable condition for cotton cultivation, would be in demand for the growth of cotton. Whatever the future production of the United States may be, it seems safe to say that the time is not far distant when other cotton-growing countries will be called upon to contribute a much larger proportion of the world's supply than is now the case. Whence, then, is this additional supply to come? It is evident it must come from some portion of the zone within 30° south and 35° to 42° north of the equator. Naturally, India would be the first looked to for supplying the larger portion of the deficiency, but experiments and years of cultivation have demonstrated that other countries also have favorable conditions in climate and soil for a satisfactory yield of the staple.

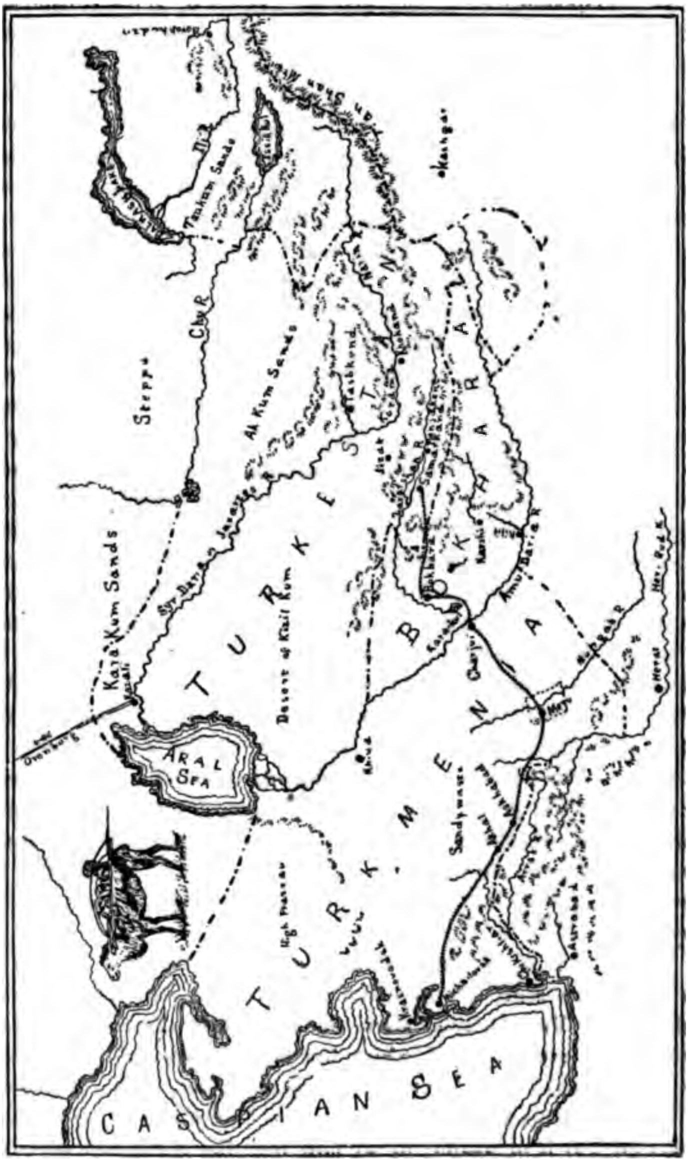
We do not presume that central Asia will ever become a great cotton-producing region in ministering to the wants of the cotton-manufacturing industries of the world or in supplying any large portion of the anticipated deficiency, but we believe that it has a future in this direction that is worth our while to consider, if in no other connection than with the manufacturing wants of Russia. The particular prominence of Central Asia, at this time, is because of the special efforts on the part of the Russian government to convert it into a highly-productive cotton-growing region, whence can be obtained the chief supply for the cotton factories of the empire. The annual imports of cotton into Russia amount to about 300,000,000 pounds, or 750,000 bales. A large portion of this quantity is American cotton, though, in 1887, only 155,753 bales were received direct from the United States. The object of Russia is to avoid these importations by raising the necessary amount for its manufactures

within its own territory; but for its finest yarns it will, with other countries, always stand in need of the cotton grown in our southern States, on the alluvial lands and upland swamps of the Mississippi River valley, and on the calcareous soils and prairie lands that are found in Alabama and westward to the Colorado river in Texas. Under the most favorable circumstances it will be many years before Russia can supply herself wholly with cotton raised upon her own soil, even for the ordinary grades of her manufactures. In 1884 the cotton plantations of Central Asia covered an area of only 810 acres, while in 1886 the area was extended to 32,400 acres, with considerable augmentations since then. In the spring of 1886 972,000 pounds of seed were sold in Tashkend, of which 900,000 pounds passed into the hands of native planters, very little being taken by Russian agriculturists. The crop of that year was estimated at 5,600,000 pounds, or at an average of 173 pounds to the acre, which compares favorably with the average yield per acre in the United States.

Whatever the future may be concerning the agriculture of this region, its development must depend on the perfection of the systems of irrigation that may be introduced. Without this method of enriching the soil and extending the area of cultivable lands, there can be no hope of elevating the vocation of the husbandman, in these parts, into an importance worthy of consideration.

The cotton fields of Central Asia are in the Aralo-Caspian depression, often designated as Russian Turkestan. The general government of Turkestan, as defined on the map accompanying this paper, covers an area of 257,000 square miles, or more than the area of Texas. The character of the surface varies from extensive plains and barren wastes to fruitful valleys and mountain peaks of lofty elevation, of which only about three per cent is devoted to agricultural pursuits, confined to the valleys of the Zarafshan and Nazin Rivers. About Tashkend American and Egyptian cotton seeds have been sown experimentally, with more or less reported success. The western provinces of Turkestan are but deserts or the pasture lands of nomads, with no natural advantages to attract the cultivator of the soil.

The state of agriculture in the district about Khokand is in a comparatively advanced and flourishing condition, owing to the excel-


CASPIAN SEA
ARAL SEA
TURKESTAN
TURKMENIA
BOKHARA
Kara Kum Sands
Steppe
Chu R.
Ak Kum Sands
Desert of Kizil Kum
Merv
Herat
Kashgar

lence and equability of climate and the fertility of soil. It compares very favorably with that found in the Zarafshan River valley; and in dependence upon natural resources it is equally as well situated. It stands in need only of an intelligent system of irrigation, which can be made feasible in connection with the river Nazin or its tributaries. Scarcely inferior to the foregoing, in fertility of soil and in conditions favorable to the prosecution of agricultural pursuits, is the Kurama district, which is spoken of by travelers as the granary of Tashkend. Here the tilled land is that lying on the mountain slopes, and is represented as capable of a high state of cultivation under civilized methods of husbandry. Much is said by writers who have visited the district drained by the Zarafshan River, of its many agricultural advantages, and its superiority in these respects to all other locations in Turkestan; but it is admitted that it is incapable of supporting a larger population than that already dwelling there, owing to the scarcity of water; and every drop is counted of value. Nowhere, probably, is there greater need of properly-regulated methods of irrigation than in this district, and these improvements must consist in methods and regulations instead of in further draining the Zarafshan river. In some of the late notices in Russian journals concerning the resources of Central Asia, the valley of the Ili River is spoken of as the richest portion of Asiatic provinces recently occupied by Russia, with special allusion to the cultivation of cotton. The valley of the Borokhudzir, a tributary of the Ili, has been alluded to in the published works of one or two explorers of the Kulja region, as being particularly productive. The climatic conditions of this district for the successful growth of cotton, in the long, dry, and hot summers and short winters, attracted the attention of Chinese immigrants some twenty years ago; and they are given the credit of introducing its culture at that time, but its prosecution has not yet been attended to very extensively.

Bokhara is in the center of an oasis, where the land is more or less productive, especially in places where it is frequently overflowed with water. The elevation above the sea around Bokhara and Karshi is a little over 700 feet, which has an influence on the climate favorable toward the growth of the cotton plant. The Bokharan oasis is looked upon as likely to become a highly-productive locality for cotton. It is impossible to say how near the truth this may be;

certain it is, great improvements will have to be inaugurated before it attains any position of this kind. Bokhara cotton today is trashy stuff, as it appears upon the market, and it possesses few qualities in length and uniformity of staple or cleanliness to recommend it for manufacturers' use. This is partly inherent, and is also due to indifferent harvesting and to the crude inplements employed in freeing the lint from the seed. Some progress has been made of late in the introduction of better methods of ginning, in the use of saw gins; but this can be better said of the methods partly in operation about Tashkend. As it is now, a large portion is scarcely worth the cost of transportation to Moscow; yet it is here that many of Russia's hopes are centred for that production which is to render Russian manufacturers independent of an American supply. Soil and climate may be propitious, but the laborer has much to learn, which means more than its simple declaration. Experiments that have been made with the sowing of American and Egyptian seeds have not proved as satisfactory as anticipated. The first year's production usually compares favorably with the original, but a deterioration at once takes place, which is readily perceptible the second year and thereafter. The same experience has been had with the yield of cotton from American seeds in other countries where experiments have been conducted. The best cotton, in my opinion, for any country, is that raised from native selected seeds under improved methods of cultivation. Hence, it is my belief that the best cotton seeds for Asiatic Russia are carefully selected seeds that are indigenous to the soil. And this has proved to be true in a certain degree in our southern States. My own observations have demonstrated to me the impracticability of reproducing sea-island cotton in possession of its superior characteristics, as represented by its Edisto type, on Galveston Bay, or anywhere on the coast of Texas, though apparently under like conditions regarding soil and climate. I may be mistaken in my judgment concerning the proper seeds to cultivate from, and it almost seems as if such were the case in the face of the many reports of the great improvements occasioned by the planting of American seeds, as has been noted by consular officials regarding the cotton from such seeds raised in the Erivan province, Caucasia, and elsewhere. Yet I am inclined to think that retrogression will in time follow, unless equally favorable climatic and other conditions can be found, which have not yet been

definitely determined. In a late number of the *St. Petersburg Journal* contrary views are entertained, and claims are put forward that all the necessary conditions exist in certain parts of Russia for the production of cotton equal in every respect to that grown in the United States. This authority says: "The numerous trials made, not only in the Caucasus and trans-Caspian region, but also in Bessarabia, the Crimea, and New Russia, leave no doubt that the cotton plant of New Orleans grows as well as in the southern States of the American Union. Since 1885 several agents have been sent to America to study cotton planting on the spot. The American trade received with visible irritation the reports relating to the eventual opening of Russian cotton growing, and maintained by its organs that good cotton could only succeed in tropical and semi-tropical countries. It has been found that Russian plantations have gone ahead of the American plantations." From the same source we learn that since the spring of 1887 vast tracts of land have been planted with cotton in the trans-Caucasus and about Tashkend and Bokhara as well as on the shores of the Amu Daria near Charjui. We are not disposed to dispute the self-satisfied claims of the Russians, and we trust that they will never be subject to disappointment, though ordinarily a few years of experimental experience in a matter of this kind would hardly be taken as sufficient to establish a certainty; and the improvements that have been so sedulously noted could just as likely be ascribed to better methods of cultivation as to the free use of American seeds. To carry on the culture of cotton near Charjui, at all extensively, artificial methods of fertilizing the soil will have to be depended on almost entirely. No tributaries flow into the Amu Daria below Kilif, and the river flows between "flat banks formed of loess and alluvial soil deposited by the water, which holds in suspension a large quantity of granitic sand." There is no natural fertility to the land. In 1876 a survey was made from Charjui to Kilif, with a view to the construction of new irrigation canals, but the leveling did not give encouraging results. There is nothing promising in these parts for the successful growth of the plant, and probably very little attention will be given to it for years, if ever. We have seen favorable accounts of cotton raised about Khiva, it being represented as of longer staple than that grown about Tashkend and Bokhara, besides being softer and more silky. The

Khivan oasis is on the left banks of the Amu Daria, and is more or less fertile, but, being only 200 miles long and 30 miles wide, it is not likely to become a cotton region of the same importance as that lying on the slopes and in the valleys of the western spurs of the Tian Shan Mountains.

Comprehensively speaking, Turkmenia has no cotton future. It may be considered as a vast desert, with only an occasional well of fresh water for a district, perhaps of 130 square miles. In the southern portion four oases exist, through which the trans-Caspian railroad passes. The most important of these oases is that of Merv, which, after all, is not a natural one, but made so by irrigation many years ago. Experiments have lately been conducted in the vicinity of Merv in the cultivation of cotton from American seeds. Fifty pounds of seed are sowed to the acre, and during the growth of the plant the land is irrigated three different times. The full crop yields an average of 1165 pounds of seed cotton, or 217 pounds of lint to the acre. This would indicate a yield of only 18.6 pounds of lint to 100 pounds of seed cotton, though it is stated American saw gins are used. The inference might be that the operation of the machine is very imperfect, or that there is a degeneracy in the character of the cotton plexus, either in density or length of staple, which I am inclined to believe is the case. I have been further informed that the cost of cultivation is about $17.50 per acre, but it is expected that this will be soon reduced at least one half, and that the yield of lint cotton per acre will be increased to 300 pounds.

Many efforts have already been made to ameliorate the varieties of cotton planted, and experiments have been made with American seeds. The variety chosen for this purpose was Sea Island, but it never seemed to occur to the reformers that Sea Island cotton owed its merit entirely to the fact that it was grown on islands on the sea coast, and that when sown on uplands or in the interior it lost its good qualities. The cotton planted in Tashkend and near Samarkand came up and grew beautifully; in fact, it kept on growing until it reached a hight of eight or nine feet, till winter came on, before any of the bolls had a chance to ripen.

A Russian writer, familiar with the agriculture of Central Asia, says that the production of cotton in the territories about Khiva, Bokhara, Khokand, and Tashkend has in the last seventy-five years

nearly doubled, and it will, beyond doubt, soon be increased ten-fold with the extension of railway construction. The government of Russia is making strenuous efforts in extending the cotton area of the Asiatic provinces, and many hopeful expressions are made that a few years only are needed to place the empire upon an independent footing regarding a cotton supply for its manufactures.

The localities of immediate interest are those occupying the lowlands of the Amu Daria and Syr Daria in the Bokhara, Khokand and Tashkend districts, which will soon have all the advantages of railway communication.

With the annexation to Russia of Tashkend, Khojend, Samarkand, and, lately, part of the Khiva's khanate, on the right (left?) side of the river Amu Daria, the northern edge of the zone of cotton culture enters imperial territory. The conditions of continental climate of this district, though not wholly favorable for raising cotton of high grades, could at least be expected to allow improvement of native grades to such a degree as to make it a substitute for East India cotton. Cotton of Central Asia, in its present aspect, has two essential imperfections by which demand for it is lessened compared with that grown in Surat,—its shortness of fiber and bad cleaning. These imperfections in the cotton of Central Asia could be removed to a certain degree, by thorough cultivation of seeds, and also by establishing improved gins for cleaning, and presses for packing. With such improvements it can be expected that the cotton of Central Asia will be substituted in Russian manufactures for that of East India.

Central Asia possesses a variety of climate. That of Turkestan is as varied as its surface. The best observations, thus far, have placed the Aralo-Caspian slope between the isothermal lines of 68 and 77 degrees, in July, while in January it is between the lines of 5 and 23 degrees. The extremes in the general temperature are represented in the summer heat of Cape Verde Islands and the winter frigidity of Canada. The heat in Turkestan, during the summer months, is described by travelers as almost intolerable,—the hot season lasting from three to five months. Except in the mountain districts, rain seldom falls. From Samarkand to Tashkend the peach and almond thrive. In 1881 observations were taken of the meteorology of Central Asia at different points. At Samarkand the

mean temperature for the year was 58.1 degrees in a range from 3 degrees to 104 degrees. At Tashkend the mean temperature was 55.7 in a range from 10 degrees below zero and 101 degrees above. The rainfall for the year, in the two places, was about 15 inches, and the mean relative humidity was about 64 degrees. I have been unable to obtain the meteorology of any portion of Central Asia for the cotton-growing season, therefore no comparison, other than yearly, can be made with the meteorology of the southern States. In 1880 the mean annual temperature at Augusta, Ga., was 65 degrees, ranging from 7 to 102 degrees. At Vicksburg, Miss., the mean annual temperature, for 1880, was 66 degrees, ranging from 12 to 101 degrees. The annual amount of precipitation for the two places was respectively 48 and 84 inches. That for Vicksburg was unusually heavy, the average annual precipitation being nearer 60 inches. The mean relative humidity for the two places was about 69 degrees. The great difference in the yearly amount of precipitation in Central Asia and in the American southern States will be particularly noted, and the importance of a perfect system of irrigation, with reservoirs and canals, under excellent regulations, will be appreciated for the former country. There is much to be desired to make the comparison good for purposes concerning the cultivation of cotton. Average meteorologic conditions are much more unsatisfactory for Central Asia than for our southern States. The conditions are far more uniform for the latter than the former. The surface elevation of the cotton-growing region of the southern States is within a few hundred feet above the sea level, while that of Central Asia varies from a few hundred to many thousand feet, making the climate, as about Khokand, partake of complex characteristics peculiar either to the tropic or temperate zone. Instead of one vast area being suitable to cotton cultivation in Central Asia, only isolated spots, comprising more or less territory, are to be found. In the valleys and along the lower slopes of the mountains the winters are usually mild, with little snow, while the summers are long and hot, with little rain.

The building of the trans-Caspian railway from the sea to the valley of the Zarafshan is an enterprise of the greatest importance to the material welfare of Russian Central Asia. Its construction was begun in 1880, with no other interest than to transport troops, food, and forage some fifteen miles into the interior. In 1885 mili-

tary necessity compelled its further extension, even to the stronghold of Merv and the city of Charjui on the Amu Daria, where its strategic importance ends. From this point eastward it assumes a purely commercial significance. It was in January, 1888, that the first rails were laid on the eastern banks of the Amu Daria, and in the following May the first locomotive entered the city of Samarkand. The railroad is 900 miles long, and is certain to exert a powerful and civilizing influence on the destinies of Central Asia. To it almost alone is due the especial attention which has recently been given to the natural resources and agricultural capabilities of the country through which it traverses. That it will in the early future be extended to Khokand, Tashkend, and the Ili river, and beyond, with tributary branches in all directions, is almost a matter of absolute certainty. The bringing of all the fertile regions of Central Asia within the reach of railway facilities will stimulate a wonderful and rapid development of the natural resources and adaptabilities of the country; and with private enterprise and government aid there is no telling what may be in store for it. The success of cotton cultivation, even presuming upon the propitiousness of the seasons, must depend on expeditious and economical means of transportation from the field to the market. Notwithstanding the railway has been extended to the heart of Bokhara and Zarafshan, much more will have to be done before the commercial importance of the country will reach the expectations of the Russian government, or before the production of cotton can be hoped for on an extensive scale enough to supply Russian factories with more than a modicum of their wants.

The real designs of Russia are too obscure to venture upon any prediction as to her future course in Asia. Whatever they may have been heretofore, in their military or commercial aspects, they certainly now have the appearance of greater devotion to the moral and industrial welfare of the people. This would be a stroke of wisdom, let the intentions of the government be what they may; and the little that has already been done has shown itself to be beneficial to the natives. The policy of Russia is usually looked upon as purely of a political nature to circumvent European influence, other than her own, in Asiatic affairs, but Schuyler, Dr. Lansdell, and others who have visited Central Asia, and studied the Asiatic policy of Russia, are disposed to think more favorably of it than consisting simply

of territorial aggrandizement. The extension of her boundaries in Asia, though apparently aggressive and possessing military significance, has thus far been confined to ethical and political lines, and would remain so even if Bokhara and Kashgar were included. Russia's political power is fully established in Central Asia, and there is no danger of her losing her present territorial possessions; and being fully aware of this she has inaugurated a policy having in view the industrial progress of the country.

MEETING 384.

Statistical Tabulation by Machinery.

BY MR. CHARLES F. PIDGIN.

The 384th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, February 14th, at 8 P. M., Prof. Davis R. Dewey in the Chair.

After the reading of the records of the previous meeting, the chairman introduced Mr. Charles F. Pidgin, of Boston, who read a paper on "Statistical Tabulation by Machinery."

Mr. PIDGIN's opening remarks related to the origin of statistics. The science, as regards census-taking, is of great antiquity, for there are several allusions made in the Bible to the numbering of the people, and the book of "Numbers" is the census-volume of the Bible.

The manner of counting first used was undoubtedly to stand the people in rows or assemble them in groups, and then actually count or number the individuals. Natural steps forward would be made after the introduction of letters and figures, and signs, symbols, or marks of various kinds would be used to record the enumeration and the necessary aggregations in order to arrive at totals.

Despite the antiquity of statistics the science made no material progress until 1790, when the United States, the youngest of nations, inaugurated the federal census, of which the eleventh will be taken in 1890.

The leading statistical associations in the world, at the present day, are the American Statistical Association; the Convention of Chiefs and Commissioners of Bureaus of Statistics of Labor; the Royal Statistical Society of London; and the International Statistical Institute, composed of the leading statisticians of the world.

In this country, since 1873, the growth of statistics has been marvelous. Instead of one State bureau, there are now twenty-one, and the National Department of Labor is finely equipped as regards material, money, and progressive officers. The people demand thorough and honest investigations, and honest and accurate presentations of results. The colleges have recognized the coming demand for statisticians, and in a tentative way are turning the attention of young men to the science as a possible vocation. Scientific men necessarily base their economic articles on statistics, and political speeches bristle with figures drawn from the statistician's laboratory. A needed advance is the addition of statistical editors to the staffs of our leading newspapers. As society becomes more complex the nature of the statistics needed for public information and use becomes "finer," that is, more in detail; and it is this great increase in the labor necessary to collect, prepare, and print statistical tables that turned the attention of inventors to the matter of providing labor-saving devices for quick computations and tabulations.

The speaker said the practical part of statistical work consisted of five branches: first, the preparation of the blanks or schedules; second, the writing of suitable instructions to guide the party filling the blank, agents, or census enumerators, in their work; third, the examination of the schedules to note omissions and to correct errors; fourth, the tabulation of the returns; and, fifth, the presentation of the results in print, accompanied by necessary explanations and analyses.

The speaker then said that he should take up only the fourth division of the practical science, tabulation, and would explain the uses of the printed and mechanical devices which he had invented and put in practical use in the Massachusetts Bureau of Statistics of Labor.

The two principal operations in tabulating are counting or tallying one at a time, and addition, or the aggregations of large numbers. Besides these two mathematical processes many averages and percentages have to be figured for use principally in analyses of statistical tables.

Counting or tallying was originally done by the use of peas, beans, shells, which were dropped into some recepticle, and then counted to arrive at results. The next move would be to make dots or checks to represent persons or things, and then count these dots or checks. We are all familiar with the four perpendicular and one cross line to indicate five. In 1875 I prepared and copyrighted a "Self-Counting Tally Sheet." Upon these sheets the dots were already printed, and the tabulator, by encircling the dots and adding certain checks, could tabulate 9000 points on a sheet six by nine inches; and, what was of particular importance, could carry out the results at once, the sheets being so arranged as to "self-count" the check marks. The self-counting tally sheet was used to prepare the population and social statistics of the State Census of 1875. Seaton's tallying machine, used in the United States Census of 1880, was ingeniously arranged to receive the check marks in prepared columns, but it was not self-counting, and the aggregations were necessarily laborious and tedious. A tallying machine used in the Royal Bureau of Statistics at Rome has figures on the peripheries of wheels, and when these upturned figures are inked with a printer's roller, impressions may be taken on paper for use as bulletins. In 1882 I used, for the first time, a mechanical device for tallying or counting. This was named the "Pascal" counting machine. It registers from 1 to 999, and beyond that, by an ingenious device, its capacity may be indefinitely extended. The single machine is intended to count one at a time only. By combination of a number of machines the series may be used for addition or multiplication.

The Pascal machine is the foundation of the "Automatic Door Counting Machine," by means of which the population and social statistics of the Massachusetts State Census of 1885 were prepared. By this machine a great gain is made over previous methods, both in speed and accuracy. With the old form of tabulation sheet but three points of statistical information were secured at a time, while the machine referred to has a capacity of 144 points at one handling of

the schedules. It is, in reality, a wooden tabulation sheet, with 144 columns, requiring no ruling, and always ready for use. It acts automatically, and the clerk has only to copy the results from the dial plates when the manual labor of classification is completed. The machine can be adapted to every kind of tabulation or statistical aggregation. It can be used as an adding machine, and can be utilized for the highest form of statistical work, including the most complicated tables. Its efficiency is from five to twenty times that of the old methods of tabulation.

For addition both printed and mechanical devices are used. The printed one is called "Self-Counting Form, for Adding Values, Quantities, and Numbers." This form, based upon the decimal disintegration of numbers, was used in aggregating the Industrial Statistics of the Massachusetts Census of 1875. It supplies a means of adding, paradoxical as it may seem, without the use of figures. To add "50,000," "100,000," or even "1,000,000," requires but one check on the sheet. The electrical adding machine is based upon this invention.

In 1882 mechanical adding machines were introduced into the Bureau. The first one used was the Pascal counter, used in a series, as previously explained. To secure the total required a peculiar result slip and some little time to add the respective columns of results. To overcome this delay a new machine, called "The Billionaire," was invented, which gave a continuous total easily read by a glance at the dial-plate. In this machine the "carrying" device was controlled by the eye, its action not being automatic. The next invention was the "Cylinder Adding Machine," in which the ear, or sound, was relied upon to govern the carrying device, and it was a material advance upon the Billionaire. The succeeding improvement was the "Button" machine, in which "touch" took the place of eye or ear, and was found to be more efficacious than its predecessors.

There is an intermediary process between counting one at a time and the addition of *large* numbers. This is the addition of *small* numbers, running from 2 to 50, or even 100. To do this kind of work expeditiously the "Rotary Counting Machine" was invent d. By its use such small numbers can be added automatically, no attention being required by the carrying device. The capacity is 25,000, and it is small enough to be carried in the pocket.

The speaker next referred to his "Electrical Adding Machine." This machine is based upon the decimal disintegration of numbers, — the same principle as was made use of in constructing the "Self-Counting Form for Adding Values, Quantities, and Numbers." The capacity of the machine likely to be most used is 999,999,999, but the capacity may be easily extended indefinitely. Machines can be easily constructed on this plan to add yards, feet, and inches; pounds, shillings, pence, and farthings; fractions,— in fact any collocation of units, the machine doing the necessary reductions automatically, and showing a consecutive total on a dial plate.

Electricity has been adopted as the motor, because it is the only power that will operate the automatic carrying device, thus saving the eye, ear, or finger the necessity of "carrying." It reduces addition to simple notation, or the writing of numbers the same as they would be written on a sheet of paper. When the "writing" on the machine is done, the numbers are added, and the total is visible upon the dial plate of the machine. Any digit may be put upon the machine with one motion, that is, a "9" can be added as easily as a "1." The advantages of the machine are numerous. It avoids brain wear. Ten hours' work with the machine is less fatiguing than three hours with pencil and paper. It places the ordinary clerk on a level with the expert accountant, and yet aids the expert by lightening his labors. Its comparative efficiency depends naturally upon the operator. Other things being equal, its efficiency is from two to six times that of the old method of computation. Besides, the weary brain is prone to error, but there is no reason why the electrical adding machine should do any the less accurate work at six o'clock in the afternoon than at nine o'clock in the morning. A cog-wheel adding machine may be broken, and the machine keep on working, but naturally giving erroneous results. On the other hand, as soon as anything interferes with the accurate working of the electrical adding machine — *the machine stops!* This machine, by a simple process, may be used for multiplication, but it is not intended to do subtraction or division.

With a view of inventing a machine, or rather a system, which would give the same opportunities for addition as the Automatic Door Counting Machine does for tallying, I devised the "Chip System." The chips are contained in a case, and are taken from it the same as

a compositor selects type when "setting." By the use of variously colored "chips," and a machine with 36 compartments, a clerk can add 144 points at once,— that is, have 144 different sums in addition going on at the same time, with 144 results when the "chipping" is completed. The chips are put back in the cases, and used over and over again.

The three grand divisions of census work, and the three machines used in their tabulation, are population and social statistics, the automatic door counting machine; statistics of agriculture, the "chip" system; statistics of manufactures, the electrical adding machine. These machines have been used successfully in the Massachusetts State Census of 1885, and are of proved efficiency.

For the figuring of percentages, Thatcher's machine has been used, but it does not give enough decimal places for advanced statistical work. The speaker's "Addition Percentage Tables" reduce the figuring of percentages to simple addition, with decimals carried to the seventh place.

Machines do not aid in the performance of the mental work necessary to block out a statistical investigation or to take a census. They are servants, and require masters. The brain must evolve the scheme or plan, and must invent the result slips upon which the work of the machines is taken down. The invention of a plan to give correlated statistics requires more brain power than to invent a machine. Each piece of statistical work requires its own "scheme," and the constructing statistician need never fear that machinery will do his work for him. With machines for tabulation and addition a statistical office becomes a "factory," in which the best results are secured by the subdivision of labor, the same as in a boot and shoe factory or a cotton mill. The tendency of machine work is to increase the character of the work done by the head clerks and reduce the mental strain on the subordinate clerks. This it does by substituting largely mechanical and lightly mental operation for one purely mental and brain wearying. This physical labor is more healthful than the purely mental, a fact attested by the time rolls of the Bureau during the past four years.

Mechanical devices in statistical work will be to the brain-wearied clerk what the sewing machine has been to the seamstress. Their use will not throw clerks out of employment, but will enable

them to do more and better work for the salaries paid them. They will make it possible for statistical officers to prepare voluminous reports with small appropriations, and will enable state and national governments to tabulate and aggregate census and industrial returns in less time and for less money than by old methods.

The speaker closed with a humorous account of a supposed visit, in a dream, to the mythical city of Statistica, where statistical records are carried to a laughable extreme. Several of the machines described were exhibited in operation.

MEETING 385.

The Nature and Uses of Asphalt.

BY CAPT. F. V. GREENE.

The 385th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, February 28th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Capt. F. V. Greene, of New York, who read a paper on "The Nature and Uses of Asphalt."

Capt. GREENE said: Asphalt is a variety of bitumen, found in a native condition and not manufactured, and in a solid form is commercially known as glance pitch. Glance pitch is found in limited quantities in various parts of the Rocky Mountains and in Texas. It is very pure, and is used to make a high grade of varnish, but its brittleness makes it useless for paving or roofing compounds.

The asphalt of Trinidad is found in a so-called "lake," about 130 feet above the sea level, on the island of that name. The "lake" is a level tract, about 114 acres in area, of brownish material of an earthy appearance. It is sufficiently hard to bear the weight of carts and animals, and yet its consistency is such that excavations fifteen

feet in depth are filled up by the flow of adjacent material in a few months. It is estimated that the amount of asphalt in the lake is upwards of six million tons. On partial analysis it yields approximately forty per cent of pure bitumen, forty per cent of earthy and vegetable matter, and twenty per cent of water. The material is heated in large tanks at a temperature of about 300° Fahrenheit, to drive off the water and let the larger portions of the earthy matter settle, and the vegetable matter be skimmed off the surface. This refined asphalt contains about sixty per cent of pure bitumen and forty per cent of finely-divided earthy matter, invisible to the eye. This material is too brittle for commercial use, and it is therefore mixed with a heavy dark oil, known as the residuum of petroleum, in the proportion of six parts of asphalt to one of residuum. This is the material so largely used in paving and roofing compositions.

On the coast of California, near Santa Barbara, and also in certain portions of Colorado, Utah, and New Mexico, are found large beds of sandstone containing from 15 per cent to 20 per cent of bitumen. Recently this material has been used for paving in cities on the Pacific coast, but it has not yet been in use long enough to prove its desirability.

In the valley of the Rhone in France and Switzerland, in Sicily, in parts of Italy, in Spain, and in Hanover there are very large beds of fine amorphous limestone naturally impregnated with bitumen, and it is from these mines that the asphalt pavements of various cities in Europe have been obtained. Those most suitable for paving contain about 10 per cent of bitumen and 90 per cent of fine limestone.

The uses of asphalt may be divided into five classes, viz., 1st, as a varnish for paint; 2nd, as an insulating material; 3rd, as a water-proofing material; 4th, as a cement in ordinary construction; 5th, as a cement in roofing and paving compounds.

In its natural state it is too brittle for any of these purposes. For varnish it is mixed with oil of turpentine, linseed oil, and shellac. Such varnishes are used on leather, producing the so-called patent leather, and on iron, the black japan varnish being well known.

For insulating compounds the exact mixture is not divulged. For water-proofing arches and similar constructions it is sometimes used in the form of a layer of mastic, made from bituminous limestone spread over the arch; and sometimes as a cement between the

joints of the bricks, the bricks being heated and dipped in hot asphalt, and the joints poured with similar material after the bricks are laid.

As a roofing material asphalt is used in the form of asphalt cement, very similar to paving cement. The roof is covered with one or more layers of felt; on this a layer of the cement is poured, and before it has cooled fine gravel or pebbles are spread over it.

The amount of asphalt used for paving is about ninety-five per cent of the total consumption.

I shall endeavor to show that the asphalt pavement is the latest, and, all things considered, the most satisfactory solution of the paving problem yet devised. It is not as durable as cast steel, nor as noiseless as velvet, nor does it afford as firm a foothold as the loose earth of a race track; but it is much smoother and less noisy than stone, much more durable than wood or macadam, is waterproof, contains no decaying vegetable matter, can be kept perfectly clean at comparatively small expense, is less slippery under ordinary conditions (as shown by careful observations in Europe and America) than either wood or stone, and it enables larger loads to be drawn by the same force and with less wear on vehicles than any other form of pavement ever used. It has thus many advantages and fewer defects than other pavements in common use.

The speaker next gave a brief history of pavements in general, so as to trace the origin and development of asphalt pavements.

He said that no improvement has ever been devised upon MacAdam's system as a road-covering outside of cities. It has also been widely introduced within cities. London has about 600 miles, and Paris 100 miles of it today. In America it has always been popular in New England cities,— three fourths of the streets of Boston are paved with it,— but it has not found favor in other cities except on streets reserved for pleasure-driving only.

Its advantages are a firm foothold for horses and a reasonably smooth surface. Its defects are heavy resistance to traffic, great cost of maintenance, and the impossibility of keeping it clean. When sprinkled it is always muddy, and when dry it is invariably dusty. These defects are inherent, and cannot be remedied. The Paris Budget shows that it costs over $900,000 per annum in that city for the single item of repairs to macadam pavements. This is equivalent to 45 cents per yard per year. It is estimated that the annual cost

of repairing the macadam pavements of Beacon Street, Boston, is 50 cents per yard.

Stone pavements were next taken up, and figures presented showing that the cost of repairs was from 5 to 12 cents per yard per year, while the annual cost for laying and maintaining the best quality of granite block pavements on concrete foundations is 26 cents per yard. Wooden pavements were shown to cost annually for laying and maintaining about 61 cents per yard; but it is now claimed by its advocates in London to be 42 cents per yard under moderately heavy traffic, or about two thirds the cost of macadam under the same conditions. Capt. Greene gave the experience of Washington as a warning against its use. Upwards of $4,000,000 derived from a loan not yet paid off were expended in that city under the Shepherd government of 1871–74 in laying fifty miles of wood pavements. They proved a complete failure in a few years, and have all been since replaced with asphalt at a little more than half the original cost of the wood.

Bituminous limestone or rock asphalt began to be used for paving in Paris in 1854, in London in 1869, and in Berlin about 1880. And its use has been continued with success. The total area of this pavement in use now in Europe is about 1,500,000 square yards, covering a length of about ninety miles of roadway.

A uniform system has been used in laying in all the cities. A solid bed of concrete is used to give a foundation. On this the asphalt surface is laid about two and a half inches thick. The preparation of this surface requires great care and skill. The asphalt rock, as it is quarried from the mines, is crushed in a rock breaker to a size of about three inches. These are then passed through toothed rollers, and again through smooth rollers until the rock is reduced to powder. This is then heated in revolving cylinders to a temperature of about 280° Fahrenheit, and the heated powder is carried in carts to the street where it is to be used. There it is spread on the concrete, and raked with hot iron rakes until it forms a uniform layer of loose powder, about twice its ultimate thickness. This is then quickly compressed by pounding with hot iron hammers, after which a small amount of hydraulic cement is swept over the surface, and the pounding is continued until the pavement will no longer yield under the rammer. It is left until the next morning to cool, when the street is opened to traffic.

In London the first cost has been about $3.75 per yard, and the maintenance 18 cents per yard per year, the street to be delivered at the end of seventeen years as good as new. Including first cost, the total expense is 40 cents per yard per year.

The success of this pavement in Europe gave rise to a demand for such pavements in America, but the expense of transportation of the rock from France was so great that inventors sought to find a substitute. They first tried the tar produced in large quantities at the gas works, which they erroneously supposed to possess the same qualities as the natural bitumen in the asphalt rock. This was combined with sand, limestone, sulphur, sawdust, etc. The material did not look unlike the real asphalt, and a craze for such pavements started in Washington in 1871, and spread all over the country.

The majority of these efforts were complete and costly failures, and, as they all claimed to be asphalt, the result was to create a prejudice against all pavements of that character, which it required years of careful experiment and proof to overcome. The defect of them all lay in the tar, which contained volatile matters which evaporated under the influence of the sun, and left the pavement a mass of dry black powder.

A Belgian chemist conceived the idea of using the asphalt of Trinidad as the cementing material, knowing that it had been exposed for centuries to a tropical sun, and that the sun's rays could have no further effect on it. With this he combined clean sharp sand and a small amount of powdered limestone. The sand in it afforded a firmer foothold for horses. It was used on a part of Pennsylvania Avenue, in Washington, in 1876; the asphalt-rock pavement of Paris was used on the other part, and they have been in constant use ever since. The French pavement proved more slippery and more costly than the Trinidad, and no more of it was laid; but the Trinidad asphalt gave entire satisfaction, and has been constantly laid with succeeding years, until now its area in Washington alone is but little short of one million yards. After seven years' successful use in Washington other cities began to use it, Buffalo being the first, and it now rivals Washington in extent of its use. It is now used in thirty-four cities, the total area being about four million yards.

These pavements are laid on a solid foundation of concrete six inches in thickness. The asphalt surface is two and one-half inches

thick, laid in a similar manner to those in Paris. But the asphalt is prepared quite differently. The refined asphalt is mixed with the residuum of petroleum to make the cement. This is heated at 300° Fahrenheit, and the sand is also heated to the same degree; these are mixed in a large box in which agitators are constantly revolving, and there a complete mechanical mixture is formed. The hot powder is then taken to the street, spread the proper thickness, and immediately compressed by large steam rollers, weighing from five to ten tons.

Of late years experiments have been made with other foundations than concrete. One of these is a mixture of broken stone and tar, forming a bituminous concrete. Another is the use of old well compacted macadam, thoroughly scraped and cleansed, and all depressions leveled up to a true surface. In both cases the object of the change is to effect a saving in cost. The bituminous base has been used in Washington, and the macadam in Chicago. Both appear to have been successful, but their complete success cannot be positively ascertained until they have been longer in use. The essential feature of the foundation is to have it solid and rigid. If any other material than concrete will secure this quality, of course it is equally good.

The cost of maintenance for the Washington asphalt pavements is about two cents per yard per year. On many of them, now ten years old, no repairs of any kind have been made, and they are still in perfect order. These streets are subjected to a very light traffic, and are kept clean. In other cities, where the pavements are not kept clean, and the traffic is heavier,— in some cases the most destructive traffic in American cities,— the expense is much larger. But under ordinary conditions the cost of maintenance does not exceed ten cents per yard per year for a long term of years. Including first cost the total expense of maintenance for seventeen years would be about 30 cents per yard per year. From this it appears that asphalt is a little more expensive than stone, but is the cheapest of the smooth pavements.

Asphalt blocks have been tried, but they are deficient in durability under heavy traffic, but they have been very satisfactory on residence streets of light traffic. These can be laid as ordinary paving stones, thus doing away with an expensive plant in every city.

On asphalt pavements the same force will draw a load three

times as heavy as on the ordinary stone pavement. The former can be kept perfectly clean at small expense; the latter has one-fifth of its surface composed of joints filled with stable filth, which cannot be removed in cleaning.

If some one gives voice to the current belief that horses are constantly falling on the asphalt, I will show him the result of careful observations in ten different cities on 786,000 horses, of which eighty-four fell on stone pavements, and only seventy-one on asphalt. The proprietors of the livery stables of Washington and Buffalo say that they invariably use the asphalt in preference to the stone pavement, and that there is far less injury to horses, as well as to their vehicles, on the asphalt.

At the close of the paper the President extended the thanks of the Society to Capt. Greene for his very instructive paper, and declared the meeting adjourned.

MEETING 386.

Artificial Fertilizers.

BY MR. WALTER S. ALLEN.

The 386th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 14th, at 8 P. M., Prof. L. M. Norton in the chair.

After the reading of the records of the previous meeting the chairman introduced Mr. W. S. Allen, of Boston, who read a paper on "Artificial Fertilizers."

MR. ALLEN said: The artificial fertilizer industry, now one of the most important of the chemical industries, is purely modern in its development, the foundation having been laid in 1840 by Liebig.

Liebig's theory, which stands today as the basis of all agricultural chemistry, may be expressed in a few sentences, as follows: —

"The foods of all growing plants are inorganic substances. Plants live on carbonic acid, ammonia, nitric acid, water, phosphoric acid, sulphuric acid, silica, lime, magnesia, potash, and iron. Many need salt. Manures, in the form of animal excrements, do not work directly on plant life through their organic constituents, but indirectly by the products of their rotting and decomposition, in consequence, therefore, of the conversion of their carbon into carbonic acid, and their nitrogen into ammonia or nitric acid. Organic manures, which consist of parts or residues of plants and animals, may therefore be replaced by the inorganic compounds into which these residues separate in the ground.

The conditions necessary for a successful fertilizer are, concisely stated, these: —

1. The fertilizer must contain one or more substances fit for plant food, and have its value only for such.

2. It must be concentrated, in order to lessen transportation charges.

3. It must be dry and finely pulverized, so that it may be evenly and easily spread.

4. It must contain its plant food in a soluble form, or in a form which will readily decompose and yield a soluble form.

5. It must not readily undergo changes by keeping, yielding a difficultly soluble or easily volatile form of plant food.

The basis of every form of artificial fertilizer is phosphate of lime, and to this may be added potash or nitrogen in some form. There are many sources of phosphate of lime, and the first of these, which found extensive use, was guano. This contained, also, ammonia and potash. The price finally became so great, on account of the gradual exhaustion of the deposits, that other sources of phosphates were sought. Bones, of course, were used, but the supply was limited. Attention was then turned to minerals containing phosphate of lime. Apatite and phosphorite are the two principal minerals which furnish the bulk of the phosphates. Apatite is found very widely spread over the world, but so far as this country is concerned the Canadian deposit near Ottawa is the most important. It varies in quality, containing as high as 90 per cent of tribasic phosphate of calcium, which constituent determines the price, varying, at Montreal, from $12 to $22 per ton.

The most important of the more crystalline phosphorites are those of the province of Estramadura, in Spain; those of the Duchy of Nassau, in Germany, known as the Lalui phosphorites; those of southwestern France, known as Bordeaux phosphates; those of northwestern France and Belgium, and the South Carolina phosphates of our own country. Among the other raw materials furnishing phosphoric acid the most important is the slag from the Thomas Gilchrist basic still process. This slag, which is rich in phosphate of calcium, is usually simply ground, and used in that condition as a fertilizer.

Many fertilizers contain potash, and at the present day the only source of this is the Slassfurth salts, which is found in central Germany.

When fertilizers contain nitrogen the sources of it are numerous. As nitrogenous materials found in commercial fertilizers the following may be named: nitrate of soda, sulphate of ammonia, dried blood, fish scraps, cotton-seed meal, linseed cake, castor-oil pomace, dried and pulverized scraps from slaughter houses, hoof and horn shavings, hair, leather scraps, shoddy waste, etc.

Great difference of opinion exists as to the relative advantages of these different forms of nitrogen, but as a rule the manufacturer uses that form which to him is cheapest.

As regards the relative value of sulphate of ammonia and nitrate of soda, field experiments indicate that each exerts a favorable influence on certain classes of plants. All nitrogenous fertilizers, before being taken up by the plant, are converted in the soil into nitrates. This is done by bacteria, and this nitrification accounts for the fact that nitrate of soda acts more quickly than sulphate of ammonia, although crops treated with the latter overtake the other in a few weeks.

As the value of a fertilizer depends entirely upon the amounts of phosphoric acid in the different states, potash and nitrogen, many methods of chemical analysis have been tried. The separation of the different forms of calcium phosphate which may be present in a fertilizer is difficult, and therefore chemists, working on the same material, but by different methods, obtained variable results.

To obviate this difficulty an association of the official State chemists was formed, which meets each year to revise these analytical methods, so that two chemists may obtain uniform results.

Instead of designating the phosphates of calcium as mono, di, and tribasic phosphates, they are now divided into water soluble, citrate soluble, and insoluble. Citrate soluble covers what was formerly known as reverted, and means that portion which, after extraction of the part soluble in water, may be extracted by a neutral solution of citrate of ammonia under given conditions of temperature. And insoluble is that left behind after treatment with citrate of ammonia.

In the United States this business has grown with great rapidity in the last twenty years. Although the occurrence of these deposits of phosphate rock in South Carolina has been known for more than sixty years, the first attempts to develop them were made in 1867. In 1867 the production of land rock was only six tons, and the first appearance of river rock was in 1870, when 2000 tons were mined; and in the same year 63,000 tons of land rock were produced; and in 1887 these amounts had risen to 261,600 tons of land rock and 218,900 tons of river rock.

Of this total of 480,000 tons about 200,000 tons are shipped abroad, and 196,000 tons are shipped to domestic ports, while the remainder is consumed at Charleston.

The rock, both land and river, contains from 50 to 60 per cent of tribasic phosphate — phosphate of lime — and from 5 to 10 per cent of carbonate of lime. The sales are made on a guarantee of 55 per cent of tribasic phosphate, with a reduction for less amount, but no account is taken of the amount of carbonate present, although this uses up sulphuric acid when treated. Prices during the last year have ruled at $6 per ton for land rock at the mine.

The great bulk of the manufactured fertilizers is used on the cotton and tobacco crops of the South, and yet a large proportion of this is manufactured in the North from raw material brought from the South. For instance, Georgia consumes about 175,000 tons, and makes about 40,000 tons, while New York consumes 30,000 tons and makes 100,000 tons. The manufacturers of the South are making more each year, and it is probable finally they will supply the cotton and tobacco fields south of Maryland.

The importance of the fertilizer industry among the chemical industries of this country will be shown by the fact that 45 per cent of all the sulphuric acid made in this country is used in that industry.

That this will continue to be the case is evident when we consider the enormous exports of grain, tobacco, and cotton made by this country, and think how many pounds of potash and phosphoric acid are carried every year to Europe in these agricultural products. This export of these mineral matters from the soil, and the failure to return to the soil the sewage of our cities, containing the mineral constituents of all the foods consumed in them, will create a demand for artificial fertilizers which must grow as the new land in the country becomes scarcer.

MEETING 387.

Arbitration and Conciliation in Massachusetts.

BY HON. CHARLES H. WALCOTT.

The 387th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, March 28th, at 8 P. M., Prof. Davis R. Dewey in the chair.

After the reading of the records of the previous meeting the chairman introduced Hon. Charles H. Walcott, of the State Board of Arbitration, who read a paper on "Arbitration and Conciliation in Massachusetts."

Mr. WALCOTT said: My purpose, this evening, is to lay before you some of the results accomplished in this State by arbitration and conciliation applied to labor questions, — with especial reference to the work of the State Board of Arbitration.

My attempt will be to speak from my own experience of the working men and working women of Massachusetts and of their employers, and to state somewhat briefly and simply what arbitration and conciliation have done in our State. It was not left to Massachusetts to discover or invent these methods of dealing with questions arising between employer and employed; but the forms and instru-

mentalities through which they are applied in our State are in some important particulars new and worthy of careful attention.

Arbitration always implies more or less of formality,—a definite issue or dispute between parties, the collection and weighing of evidence, the hearing of arguments, and a decision that shall be binding in law upon all who have joined in the proceedings. *Conciliation* seeks to remove causes of dissension before a rupture has actually occurred, and to bring the parties into such relations with each other that they can agree upon a settlement without a formal hearing or decision. Or if hostilities have already begun, the first step in conciliation is to induce the parties to resume their former relations,—the employer to open his factory and start up his engines and machinery, the operatives to return to their looms or benches. When this is achieved the work of conciliation is more than half accomplished. The air is cleared, imaginary grievances vanish, and all the conditions are favorable for such inquiry and discussion as may be necessary to ascertain any real cause for complaint. If the question is one of wages, arbitration generally follows mediation and brings the process of conciliation to a close; and when the decision of the Board is arrived at it finds all parties in a frame of mind well adapted to accept and apply the recommendations of the Board reasonably and fairly. It has been well said that the function of conciliation is admirable and praiseworthy. It exerts its beneficent influence upon the parties to a dispute by removing old feelings of bitterness and distrust, by inspiring them with respect for each other, by fostering a spirit of independence, by compelling a recognition of the dignity of labor as well as the necessity and usefulness of capital.

(The speaker next gave a short historical account of arbitration and conciliation, as practiced in foreign countries. He then continued:—)

From all the information thus far obtained from foreign countries, the conclusion is derived that wherever and whenever arbitration and conciliation are recognized as the best means of settling disputes, there are found the highest wages for workmen, and the best production and greatest prosperity for the manufacturers. This evidence from foreign countries has great value for us, and is worthy of careful consideration by all practical men.

The subject of arbitration was brought into prominence in Mas-

sachusetts through the astonishing rise and growth of the Knights of Labor. One of the aims of that order is declared to be "the enactment of laws providing for arbitration between employers and employed, and to enforce the decisions of the arbitrators;" also "to persuade employers to agree to arbitrate all differences which may arise between them and their employees, in order that the bonds of sympathy between them may be strengthened, and that strikes may be rendered unnecessary." In order to put in practice the principle here announced, joint boards of arbitration, as they were called, which were composed of equal numbers of manufacturers and workmen, were formed in some of the shoe manufacturing towns. There was, however, one essential element lacking in these boards. No umpire was provided for, and the result generally was that after repeated sessions and a great many indecisive votes, and when everybody was tired of wrangling, some one would change his vote, and so bring the matter to an end, but at the risk of being stigmatized as a renegade to the cause which he had been put forward to advocate. In these contests it was simply a question of physical endurance. The boards were composed, at the outset, of irreconcilable elements, and the decisions arrived at in the manner just described were not such as to commend themselves on their merits or to invite a repetition of the process.

There is no doubt, however, that these joint boards, by bringing employers and operatives together on terms of equality, were productive of much good, and the benefit would have been perceptibly greater had there been an umpire in the background ready to step in and decide questions in the event of a dead-lock. Herein is one of the principal merits of our present law, that not only does it provide for a fit representation of capital and labor, but it secures also a permanent umpire or referee. Without him you may have a well-devised system of checks and balances, but the more nearly perfect it is, by so much is action or decision rendered difficult or impossible.

Three years ago the General Court of Massachusetts enacted a law which, according to its title, was intended "to provide for a State Board of Arbitration for the settlement of differences between employers and their employees." The Governor was charged with the appointment of the Board, and it was provided that one member must be an employer or selected from some association representing employers of labor; another was required to be a member of some

labor organization and not an employer of labor; the third member of the Board is appointed in the same manner, but upon the recommendation of the other two. While all are in theory of the law impartial, he really holds the position of umpire.

The Board has been made up in accordance with these provisions to consist of an employer, who is a practical man of business, and well versed in the customs of trade, a shoe-cutter, who is also a member of the Knights of Labor, and a lawyer.

Lest it may be thought that the functions of umpire are unduly emphasized, I may say that it is a pleasure to recall the fact that the peculiar qualifications of the other members of the Board, as representatives, respectively, of capital and labor, are of the greatest service and value in enabling the Board to secure the confidence of both sides, and to communicate readily with them. Furthermore, I must not omit to say that in every case that has thus far arisen, the Board has acted as a unit when the time for decision had arrived. And if, during the consideration of the subject, a dissenting voice has been raised, it has never been heard outside of the limits of the consultation room. This unanimity is, under the circumstances, not the least noteworthy incident of the subject which we are treating, and undoubtedly tends to add force to all the recommendations made by the Board.

Upon receipt of an application in writing from an employer, or from a majority of the employees in any department of the business in which a controversy occurs (and such employees may be represented by a duly authorized agent), it is the duty of the Board to visit, as soon as may be, the place where the dispute is, make careful inquiry into the cause of it, hear all persons interested, and make a decision in writing advising the parties what, if anything, ought to be done or submitted to by either or both to adjust the dispute.

These provisions apply when the Board is called upon by either or both of the parties to the controversy, and under this part of the law the more formal work of the Board of Arbitration has been done. Here everything is judicial and regular, and not materially different from any ordinary reference, except that everything is done under the broad shield of the Commonwealth. There is no strike or lock-out, or if one has occurred, it is at once ended, operations are resumed and continue until a decision is reached. In such cases the

decision is binding for the term of six months upon all who join in the proceedings; but either party may give to the other notice in writing that he does not intend to be bound by the decision at the expiration of sixty days from the giving of such notice. The term of six months has been found by experience to be convenient in arranging price-lists for manufacturers in this State, and is naturally suggested by the customs and movements of trade. Should the Board however fall into any serious error, and persist in it, the statute gives either party the opportunity to change the situation within sixty days by giving notice. Twice only has it been attempted to annul a decision in this manner. In both of these cases the recommendations of the Board continued in force, notwithstandfng the assaults made upon them.

But it is not a Board of Arbitration alone that is provided for by our law,—a tribunal that shall hold its sessions in due form, hear evidence and arguments, and give formal decisions. The functions of mediation and conciliation are added; and whenever in any manner it comes to the knowledge of the Board that a strike or lock-out is seriously threatened or has actually occurred in the Commonwealth, involving any person or corporation employing not less than twenty-five persons in the same general line of business, it is the duty of the Board to put itself in communication as soon as may be with the parties, "and endeavor by mediation to effect an amicable settlement." If a strike or lock-out has actually occurred, and the efforts of the Board to bring about an understanding prove fruitless, it may, if it deems such a course advisable, proceed to investigate the cause or causes of the controversy, without an application from any one, ascertain which party thereto is mainly responsible or blameworthy for its existence or continuance, and make and publish a report finding such cause or causes, and assigning such responsibility or blame. It was made the duty of the Board, after certain preliminaries, to "advise the respective parties what, if anything, ought to be done or submitted to by either or both to adjust" their disputes.

"Ought to be done or submitted to." The action of our legislators, on its face, presupposes a "higher law" than the Public Statutes, a broader equity than is recognized or administered by judge and jury. In point of fact, the matters considered by the Board have been chiefly questions of wages, hours of labor, the imposition

of fines for imperfect work, and the discharge of workmen. The question of wages, which is almost always the real question, although some other matter may have been forced temporarily into prominence, frequently involves a careful inquiry into the capacity and practical working of new machines, a conscientious comparison of rival machines, and their respective merits when brought into competition with work of the hands unaided by mechanical devices.

Were I to express in formal language my estimate of the value of the Board and the extent of its influence as an economic force affecting the industries of the State, I might perhaps seem to claim too much for it. But it is by its practical efficiency, and not on any sentimental or theoretical grounds, that the Board ought to be judged, and by this test must its usefulnsss be demonstrated. On this head I might quote the words of manufacturers, who say that the fact that there is such a Board to appeal to renders it easier for them to agree with their employes, aud that the decisions of the Board have made it possible for them to do business in this State at a profit, when otherwise, to avoid constant bickerings and pecuniary loss, they would have been compelled to remove their business to the villages of Maine or New Hampshire. There is also the testimony of workingmen that they never received the recognition which they craved, and thought themselves entitled to, until they met their employers face to face, in the presence of this Board, and were, for the time at least, treated as equals.

To the casual observer this may appear to be a small matter, but the wise judge better, for they know that life and property cannot be permanently secure under any form of government if the poor and the hard-working members of society are persistently shut out from association and sympathy with the more fortunate, and are placed in an inferior and degraded position merely because they are forced to earn their bread by labor, and to receive their compensation at the hands of an employer in the form of wages.

It has been proved by experience that the State Board can prepare long and complex lists of wages which commend themselves as practicable and fair to employers and workmen, not only those immediately interested as parties, but generally in the trade to which they belong. Over a year ago prices were made for cutting granite in Boston and the immediate vicinity. The superintendent of one of

the Cape Ann granite companies called on us a short time ago to obtain a copy of the Board's list. A question had arisen between him and his men which he thought could be solved by reference to our list, and he had lost his copy of that decision. I asked him what he thought of it as a practical working list. He said that he had studied it carefully, and considered it the best price-list that had ever been made for cutting granite. This was a repetition of what we had heard in other quarters, but it was gratifying to hear from such authority that the list had stood the test of a practical application for more than a year, especially as the Master Builders' Association of Boston, and some workingmen even, took great pains to impress upon us, and upon the public through the newspapers, before we undertook that case, their conviction of the absurdity of three men who were not builders or stone-cutters attempting to make a price-list that would have any practical value.

Similar testimony has been received in abundance concerning prices recommended by the Board, from time to time, in the various departments of shoe-making and in other industries.

A year ago the capital city of our State was threatened with a general strike on the lines of one of the street railway corporations. The men employed in shoeing the horses struck for higher wages. The corporation refused to allow any advance, on the ground that the wages were already higher than were paid in other cities for this kind of work. New men were employed, the old hands became excited, and having no work to keep them busy, and perhaps not finding their homes altogether pleasant under the circumstances, passed the time in the saloons and at the corners of the streets. Being approached by the agent of the State Board, they spoke contemptuously of it, and said that poor men like them would have no standing with the Board when opposed by men of wealth and influence representing rich and powerful corporations. There was need for the exercise of tact and patience before these men could be induced to entertain a suggestion that they meet the Board and state their complaints. But when at length their committee appeared at the rooms of the Board, and entered upon a discussion of their grievances, in a frank, informal way, confidence soon took the place of distrust, and they went away to advise their associates to place their case in the hands of the Board and act under its advice. It should be remarked that no

promises or inducements were held out by the Board, or by any member of it, to produce this result. The Board simply helped them to "see clear and think straight," and by causing them to view the situation as it actually affected them and their families brought them to see the folly of trying to obtain anything by a strike.

The next step, and one no less difficult than the first, was to persuade the officers of the corporation to join in submitting the matters in dispute to arbitration. The advances of the Board in this direction were courteously received by the officers, but they were fully convinced of the justice of their position in relation to the matter, and were annoyed by the action of the strikers. There was, perhaps, some anxiety for the future,—some fear that the strike would spread to the other employes of the road, for, although the officers expressed themselves confident of being able to procure all the horse-shoers they stood in need of, in point of fact they had not yet done so; and even if they succeeded in obtaining a sufficient number who could be relied upon to withstand the solicitations of the disaffected, there would necessarily be some friction caused by the opposition of the disaffected ones, and the other employes were already being affected by the complaints and threats of the strikers. After full consideration the corporation agreed to re-employ all the men who had struck, excepting one only, who, it was thought, had been over zealous, and then to leave all the matters in dispute to the decision of the Board. The exception of the one man who was objected to nearly upset the negotiations, but the officers of the corporation remained firm on this point, saying that they would not consent to do more than they had stated, and that so much was yielded by them in consideration of the fact that the Board had advised it. With considerable difficulty the workmen were persuaded to return to work, notwithstanding the fact that their comrade was barred out; and now nothing remained except to hear the parties and give a decision which would be binding upon all.

The corporation appeared at the hearing by its president, its attorney, and some other of the directors. The men were represented by a committee. After a prolonged discussion, which was helpful to the Board in judging the case, and cleared up some misunderstandings which had arisen, a decision was announced which was fairly satisfactory to both sides.

It is safe to say that after this experience the officers of the corporation understood better than ever before the real disposition and wants of those workmen, and that the men brought with them from the discussion a greater respect for their employers, and with clearer ideas and more knowledge on the subject of wages than they had ever previously acquired. More valuable result even than this,—they realized as never before that the laws under which they lived were made with some reference to them and their needs and wants.

It may also be remarked that the settlement attained in this case through the instrumentality of the State Board was of practical benefit to the public, by removing all apprehension of a general strike on the railway in question, which would necessarily have caused great inconvenience to those who were accustomed to use its cars in traveling about the city.

The question is frequently asked in what proportion of cases decided by the Board are its recommendations accepted. The inquiry is a pertinent one, for all systems of government or methods of business must eventually stand or fall when judged by the practical results accomplished. I have recently reviewed the work of the Board in order to be able to report results as correctly as possible, and I find but one case in which either employer or employes failed to accept the decision of the Board in a case submitted jointly under the forms and with the agreements specified by law. In one instance a strike had occurred; the Board interposed, and prevailed upon the operatives, who were chiefly women, to return to work, being influenced thereto by the promises of the employer previously given that he would join in submitting the dispute to the decision of the Board. The employer actually signed the application and agreement in the presence of the Board and with full knowledge of all the facts.

The representatives of the operatives signed also, and the strikers returned to work. This result having been obtained the employer notified the Board that he had changed his mind, had sold his machines, and notified his employes that they were discharged, and that he should not take part any farther in the arbitration proceedings. The Board published a report of the facts, and stated in conclusion that in the opinion of the Board the action of the employer was a violation of his promise and written agreement. He accomplished his purpose, but I do not think that another manufacturer can

be found in Massachusetts who would adopt so discreditable a method of adjusting a difference of opinion about the amount of wages that ought to be paid to the women and girls employed by him.

In some instances, as would naturally be expected, when the Board has held the position of mediator, and in cases submitted by one side only, the advice given has not been at once accepted and acted upon by the persons who appeared to be in the wrong or were advised to do something distasteful to them. But in some cases of this kind even the moral influence of the Board has been so strong that its advice has in the end prevailed. The few instances in which the employer or employes have declined to accept the advice or receive the assistance proffered by the Board in the name of the State can for the most part be easily accounted for. Their reluctance may arise from doubt as to the justice of their cause, or from a plentiful lack of information concerning the Board and its methods of procedure, or, most preposterous of all, it may proceed from the selfish determination manifested by some men to have their own way simply because it is theirs,—or, as one coolly expressed it, "right or wrong," he would have it so. Pride, selfishness, and ignorance are the chief obstacles in our path. They are old offenders, and the world has been a great sufferer by reason of them.

I have touched upon a few points which were suggested by the practical workings of arbitration and conciliation in Massachusetts. Many others urge themselves upon our notice, but I must hasten forward. The history of our Board is a short one, covering a period of less than three years, but it has certainly exceeded the expectations of many who were willing that the experiment should be tried, but were not very sanguine as to results.

It has, I believe, favorably impressed those with whom it has come in contact; and with the community at large it has won a reputation for honest, painstaking endeavor to promote kindly feelings and just relations between employers and workingmen.

The influence of the Board in this direction is certainly great, but it can no more be measured and weighed than can the moral influence which issues every week from the two hundred pulpits of Boston. The Board is not invested with any compulsory powers; it simply advises and recommends, and when unable to induce the parties to come to any understanding whatever, it may pass judgment in

the name of the State, and assign the blame for the existence or continuance of the controversy.

However the advice offered may be received in particular cases, the Board never forgets that it is a board of conciliation as well as a tribunal empowered to judge and report.

In view of some recent events I will, with your permission, quote from the Board's annual report, which was submitted to the General Court last month.

Reference is there made to the obstacles to mediation in certain cases of difficulty, arising between an employer and a labor organization to which his employes for the time being do not belong. The same remarks are applicable when on the one side is a compact, well organized association of manufacturers, acting through their executive committee, and on the other a labor organization, acting also by its committee. The report says: —

"Such contests, although sometimes unavoidable, are generally productive of loss to both parties, of more or less disturbance of the public peace, and the mental and moral unsettling of many individuals. So long as the contest rages, with no desire on either side for a settlement of real or imagined grievances, there is obviously no place for a board like this. If the persons directly involved prefer to carry on a controversy in this manner, after being informed of a better way to effect a settlement, the public can only stand aloof and insist on preserving the peace. Even under circumstances like these the Board has always held itself in readiness to respond to any change of disposition that might show itself on either side, and so afford an opportunity for milder councils to bring order out of chaos. We can afford to wait, for the results of such cases invariably prove the superior practical value of arbitration and conciliation."

Whenever a strike or lock-out occurs, involving a considerable number of people, and the parties, one or both, prefer for any reason to neglect the means provided by law for the settlement of disputes of this character, the complaint is certain to come from some quarter that the power of the Board should be increased, and that there ought to be some way provided for compelling people to be reasonable and just in their relations to those with whom they are associated in productive industry. The mere suggestion that the Board should have power to enforce its decisions is in itself gratifying evidence that the

decisions thus far made are in the public estimation worthy of enforcement.

Without expressing any opinion of my own concerning the wisdom of these suggestions, it should be borne in mind that if any form of compulsory arbitration, as it is called, is ever adopted, some way must be devised by which employer and employes may come equally under its influence. The employer being an individual, a copartnership, or a corporation, could always be found and identified by a person armed with a legal process; but the employer must necessarily be left at liberty to abandon his business rather than pursue it at a loss under an unfavorable decision of a board of arbitration. On the other hand, it is difficult to conceive how any process could be framed under which hundreds of men and women should be compelled to work in accordance with the terms of a decision which, in their estimation, would not provide for them a fair return for their labor. Any legislation proposed with such an end in view would be justly liable to the objection that it was attempting to legalize slavery.

I apprehend that the popular notion that the State Board should be endowed with greater power and a larger jurisdiction arises from a misconception of the power that is now exercised by it, and the extent of the beneficent influence now exerted by it on a plan that is purely voluntary.

I believe that the modern practice of providing for the exercise of some of the important prerogatives of government by the agency of State commissions had a wise origin, and is founded on a true appreciation of the power of public opinion, and the desire and capacity of the people to judge fairly and with accuracy the acts of the masses, and individuals who form the community in which we live. In process of time, and that, too, before many years have passed over our heads, we shall wonder at our distrust of the efficacy of public opinion as a compelling force; and that men, or associations of men, be they employers or workmen, who shall dare to assert a selfish preference for a course that meets with the condemnation of an intelligent public sentiment will be seen of all men in their true light, as opponents of the power which gives rise to all legislation, and makes possible the enforcement of laws for the protection of life and property. "It is not Lord Granville himself," says Matthew Arnold, "who determines our foreign policy and shapes the declara-

tions of Government concerning it, but a power behind Lord Granville. He and his colleagues would call it the power of public opinion."

If this be a true statement, as it no doubt is, of the influence which controls the relations of Great Britain with other countries, how infinitely more important it is that this influence be not neglected nor underrated in a country where "all men are born free and equal," and the principles of popular representative government are more firmly established.

MEETING 388.

Prison Reform.

BY PROF. FRANCIS WAYLAND.

The 388th meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, April 11th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, and the election of new members, the President introdueed Prof. Francis Wayland, of Yale College, who read a paper on "Prison Reform."

The speaker contended that the conceded increase of crime beyond the increase of population was due partly to the ignorance, partly to the indifference, and partly to the cowardice of the community. He illustrated this by the action of New York with reference to prison labor during the last quarter of a century, terminating in the passage of the "Yates bill," at a special session of the Legislature of that State, last July, which virtually condemned the entire prison population of the State to a condition of absolute idleness.

To the question, Has there been no improvement in our prisons for the last fifty years? Prof. Wayland replied by describing the deplorable condition of all the prisons one half century ago, when prisoners of all ages and all degrees of crime were indiscriminately

mingled in vile dens of filth, Connecticut leading the way with her prison in a disused copper mine in Simsbury. Today, in most prisons in the northern and western States, the condition of the prisoner as to light, heat, ventilation, drainage, and food is reasonably good. Some attention, moreover, is paid to mental and moral instruction. But the fact remains that crime is on the increase. How shall we account for it? Not alone by the importation of foreign convicts, though that is a factor too important to be overlooked; nor by the condition of our county jails, which, as a rule, are schools of crime. We must go deeper than this, and pronounce the underlying theory of punishment radically wrong. Though no longer vindictive, as it was a century ago, it is in purpose largely retributive; that is, it is an attempt "to make the punishment fit the crime,"—to weigh out so many years of confinement against such a measure of crime.

Now this is impossible, and would be undesirable if it were possible. It is impossible, first, because no legislative decree can ever predetermine the true measure of guilt to be attached to any given offence. There are circumstances to be considered in estimating the amount of criminality which cannot be foreseen.

Secondly, it is impossible, because no magistrate is mentally or morally capable of weighing out, with even a faint semblance of fairness, so much punishment against so much crime. The object of judicial inquiry is to ascertain whether the accused committed the offence with which he is charged. The antecedents of the prisoner, his early environment, and the like, the sentencing magistrate can know nothing of.

The evils resulting from this lack of knowledge are daily demonstrated in our courts of justice. There is no uniform principle in accordance with which judicial sentences are awarded. Frequently their severity or mildness depends upon the temperament or disposition of the presiding judge. This was illustrated by several instances. A shrewd criminal lawyer will see to it that his client comes before a tender-hearted judge. Moreover, it is a part of the unwritten law that a prisoner who, by pleading guilty, saves the officials the trouble of trying his case, will escape with a comparatively light sentence. Often courts are influenced by public feeling as to the prevalence, at the time, of some variety of crime. Then the earliest culprit caught suffers for the undetected residue. The lecturer cited several cases in support of this.

All this shows an inequality of attempted retribution which is almost universal. A distinguished criminal judge in this country, after thirty years' experience, recently exclaimed, "I am by no means certain that I have ever given a correct sentence!"

In the next place, arbitrary sentences are undesirable, first, as to the convict. If the true object of confining criminals is to protect society by secluding and reforming the offender, the only logical result is he should be confined till he is reformed. Nothing can be more absurd for the State to say to a confessedly unreformed convict, "You must be turned loose on society the moment the prison clock strikes twelve" on a given day; and yet, under our system of time sentences, a large majority of convicts are liberated who are avowed enemies of society, and intend to get their living by pillage and violence.

Again, time sentences are undesirable because of their effect on the criminal. If a man knows that his reformation has nothing to do with his release, a powerful motive for his reformation is withheld. The worst punishment which can be inflicted on a confirmed criminal is to keep him in confinement until his criminal impulses are removed. Such criminals prefer a long-time sentence at Sing-Sing to an indeterminate sentence to the Elmira Reformatory. If it is said that it is unsafe to intrust the power of discharge to prison managers, it may be replied that we are daily witnessing the same power exercised by experts in insanity, even where the insanity is homicidal, and we know that they often make mistakes which lead to fatal results, but nobody thinks of depriving them of this power.

A further step is indispensably necessary, viz., the permanent confinement of incorrigible offenders,—in other words, professional criminals, for whenever a man has demonstrated that he cannot safely be at large, he has forfeited his right to be at large.

Prof. Wayland stated further that the principle of the indeterminate sentence for first offences has been legalized in New York, Ohio, Pennsylvania, and Massachusetts, and that the permanent confinement of incorrigibles had been legalized in Ohio and Massachusetts, and their confinement for twenty-five years in Connecticut.

A long and interesting discussion followed the reading of the paper, after which the meeting was brought to a close by a vote of thanks to Prof. Wayland for his very interesting lecture.

MEETING 389.

Electric Railways.

BY CAPT. EUGENE GRIFFEN, U. S. A.

The 389th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 25th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, and the transaction of some business, the President introduced Capt. Eugene Griffen, U. S. A., who read a paper on "Electric Railways."

Capt. GRIFFEN said: The electric motor is not the discovery of any one man. Some of the greatest scientists in history have contributed to the development of this machine. Barlow in 1826, Jacobi in 1834, Davenport in 1837, Davidson in 1838–39, Cook in 1840, Elias in 1842, Froment in 1845, Page in 1850, Du Moncel in 1851, and many others were pioneers in this direction. All those early forms of motors were of course actuated by voltaic batteries. Thomas Davenport, a blacksmith of Brandon, Vt., is entitled to the honor of building the first electric railway. In the autumn of 1835 he set up a small circular railway at Springfield, Mass., over which he ran an electro-magnetic engine. He exhibited this road in Boston, for two weeks, in December of the same year.

One of the most interesting of the early experiments in electric railways was that with the Page motor, in 1851. Prof. C. G. Page, of the Smithsonian Institute, had been working in this direction for some years. In 1851 he constructed a large motor, capable of developing sixteen horse-power. This was mounted on a car, and supplied with a current from a battery of 110 Grove nitric-acid cells. On the 29th of April, 1851, he made a trial trip from Washington to Bladensburg over the tracks of the Baltimore and Ohio Railroad. The distance of five miles was run in thirty-nine minutes. A maximum speed of nineteen miles per hour was attained on a level, and this speed was maintained for a mile, until one of the cells cracked, the battery being weakened proportionally.

All this early work was useful in stimulating scientific investigation and invention, and in gradually developing better forms of motors, and establishing the true principles on which they should be constructed. The commercial and practical results were nil.

Electricity is obtained from voltaic batteries by the consumption of the zinc plates. Zinc is too expensive a fuel to compete with coal.

In the meantime the dynamo-electric machine had been developed, and in 1864 Pacinotti, for the first time, enunciated the principle of the reversibility of this machine, which is the foundation of the modern method of transmitting electrical power to a distance. He described his machine as one that could be used to generate electricity on the application of motive power to the armature, or to produce motive power on connecting it with a suitable source of power.

A more sensational discovery of this principle of reversibility is related in connection with the Vienna Exposition, in 1873. Several Gramme dynamos were to be exhibited. A workman, seeing a pair of loose wires near one of the machines, connected them to the proper binding posts, and, to his astonishment, the armature immediately began to revolve. Upon investigation it was found that the other ends of the wires were connected with a machine in operation, the source of power being a steam engine. Whether the result was attained accidentally or purposely, it was undoubtedly the first instance of the transmission of power to a distance by means of an electrical current generated by a dynamo-electric machine. The future history of the world will be greatly affected by this discovery.

The dynamo or generator and the motor are theoretically the same. If a steam engine be belted to an armature pulley, and the armature pulley be made to revolve, a current of electricity is passed through the machine, the armature is made to revolve, and by belting to the armature pulley mechanical power is available. In this way one dynamo will convert the mechanical power of the steam engine into electrical power, and the electrical power may be carried through the wires to the second dynamo, perhaps five miles away, where it is reconverted into mechanical power, and so made available for any desired purpose. The second dynamo is called the motor, and differs from the first, not in principle, but only in details which make it better suited for its special work. In this way we do away with the

zinc fuel, and come back to coal, except in those places where we are fortunate enough to have water power.

A brief description of the dynamo or generator, and the motor, is essential to a proper understanding of this subject.

The modern dynamo-electric machine is simply an application, on a larger scale, of Prof. Faraday's discovery, that, if a wire be moved through the magnetic field of a permanent electro-magnet, a current of electricity is produced in that wire. A dynamo machine consists of a pair of field magnets, between whose poles or extremities revolves a soft iron rotating support, wound about with a series of coils of wire, in which the current is developed. The revolving body is called the armature. It is generally made to revolve by belting a steam engine to a pulley on the armature shaft. As each wire moves through the magnetic field of one pole of the magnet, the induced or generated current in the wire is in one direction; as the wire moves through the field of the other magnet pole, the current is in the opposite direction. The current taken from the poles of the machine or generator, as it is usually called, would therefore be alternating were it not for the device called a commutator. This consists of a copper cylinder on the armature shaft, divided into as many segments as there are separate coils of wire in the armature, each segment insulated electrically from the others, and connected with its own armature coil. This commutator revolves with the armature, and against it are pressed two copper brushes, as they are called, which do not revolve. These brushes are the current collectors, and when they are connected by a metallic wire, five inches or ten miles long, so as to close the circuit, a direct current flows through this wire as long as the armature is made to revolve. Without going into details, it is sufficient to say that the brushes are so placed that, as each segment of the commutator comes in contact with the brush, the induced current in the corresponding wire is flowing in a constant direction, so we have a direct instead of an alternating current. As a matter of fact, the armature is not made up of separate coils, but the connections are so made with the commutator segments that we may theoretically regard the coils as separate.

The motor is practically the same as the generator, except that the power applied is electrical energy, and the power obtained is mechanical. The current coming from the generator goes to the

brushes on the motor, thence to a segment of the commutator, and so to the armature coils. The wire with a current flowing through it in a given direction is repelled by one pole and attracted by the other. The powers of attraction and repulsion compel the armature to move; it revolves, and we have mechanical energy. We gear the armature to the car axle, and we have motion.

There are two general methods of using electricity for the propulsion of street cars: —

1. The direct method, by conductors extending from the dynamo along the track.

2. The indirect method, by the use of storage batteries, secondary batteries or accumulators.

In the direct method the conductors may be overhead, under ground, or on the surface.

In the conduit system the conductors are placed in a conduit between the rails or between the tracks. The wires must be bare, and yet must be thoroughly insulated from the ground,— a condition very difficult to obtain under such circumstances. A slot about five-eighths of an inch wide gives access to the conductors by means of a contact plow; but, unfortunately, also permits the flow of water, slush, mud, etc., into the conduit. The present stage of the art in this respect is illustrated by the conduit on Boylston Street, in front of this building. It is not a success.

The overhead wire is suspended from poles by brackets or from cross wires, which span the street between poles on either side. When the street is of sufficient width, poles are placed in the center of the street between the two tracks, with bracket arms carrying the conducting wires. These poles are placed about 125 feet apart, and from actual experience are found to present little or no obstruction to traffic. The wires may be single or double. When single wire is used, the rails are utilized for the return current. When two wires are used, one wire carries the outgoing and one the return current. Contact is obtained with the wire by an over-running or an under-running trolley. The over-running trolley is a light carriage with one or more wheels resting on the wire. A flexible conductor carries the current down to the car. The trolley is pulled along by the flexible conductor. The objections to the over-running trolley are that it is difficult to keep the trolley on the wire, it is difficult to replace the

trolley when it comes off, and any automatic system of switching onto a turnout, branch, or Y is impossible. The latter is such a serious objection that, except in special cases, the over-running trolley will never be used. In the under-running trolley a light arm of the requisite length is mounted on the top of the car, reaching up to the wire. A wheel on the end of the arm is pressed up against the wire by means of springs at the other end, and the current is carried from the wheel down through the arm itself, if made of metal, or through wires if the arm is made of wood. This arm is usually called the contact-bar. The under-running trolley is automatic in its action at curves, turn-outs, switches, etc., and follows the direction of the car. It turns on a swivel through the entire circle, and moves through an arc of ninety degrees, in a vertical direction.

In the storage system a battery of about 120 cells is carried on the car, and the motors are driven by the current from this battery. The advantages of this system are: —

1. The cars can run on any track.

2. No wires, either overhead or underground, are required.

3. Each car is more independent than is the case in other systems.

The disadvantages are: —

1. The extra weight of about two tons on each car. The power required to carry this dead weight, in addition to that required to drive cars by the other methods.

2. The lack of efficiency in the batteries. The highest efficiency claimed is 82 per cent. The actual practical efficiency is stated by many authorities as about 70 per cent.

3. Storage cars cannot be regularly operated on grades exceeding 5 per cent or 6 per cent. The power required on grades makes too great a demand on the batteries.

4. The expense. The cost of two sets of batteries per car is about $3000.

5. The cost of maintenance. Batteries have not yet been made of sufficient durability to be operated economically.

There are four qualities which the electric motor must be shown to possess before it will be generally adopted for street-car work. These are efficiency, economy, durability, and reliability.

1. As to efficiency: —

The steam engine is not an efficient machine. If we can utilize 15 per cent of the units of energy stored in the coal, we are fortunate. In other words, we must expect a loss of 85 per cent of the heat units in converting the other 15 into mechanical power.

The dynamo-electric machine, on the other hand, possesses a high degree of efficiency. No good generator runs below 92 per cent efficiency. The loss in the line depends upon the amount of copper used in proportion to the current to be carried. The size of the conductor is generally calculated for a loss of 10 per cent. The efficiency of the motor, under favorable circumstances, has been shown to be but little below the generator,— in actual tests running as high as 91½ per cent. In practice it would not probably be taken higher than 85 per cent. Starting, then, with 100 horse power in the steam engine, we lose 8 per cent in the dynamo in converting the mechanical into electrical energy. The output of the generator is then 92 horse power. In the line we lose 10 per cent, and deliver 82.8 horse power to the motor. Here we lose 15 per cent, and on the final reconversion into mechanical energy on the car, we have 70.4 horse power out of the original 100 horse power. By no other known method could this power be transported to such a distance with so little loss.

2. Economy: —

This is, perhaps, a quality which appeals more directly to the railway official than any other. What will it cost? An electric railway connects Omaha with Council Bluffs, across the new bridge. I am credibly informed that to run twenty cars per day they consume five tons of slack, for which they pay $1.14 per ton. This is 28½ cents per day for fuel. These cars are scheduled at fifteen miles per hour, and the average daily mileage, per car, is over 100 miles. Where natural gas or water is available fuel may be even cheaper. On many different roads, from numerous measurements, it has been found that where the grades are slight the power required averages from 5 to 8 horse power per car. The consumption of fuel varies from 3 to 6 pounds of coal per horse power, according to the style of engine and its more or less economical operation. Of course, a road operating only one or two cars would show abnormal results in every way, and these averages are only true of roads operating a number of cars, ten or more. The wear and tear on the generating plant does not exceed 3 per cent. The depreciation on line work does not exceed

or even equal 10 per cent. The depreciation on car equipment has been variously estimated at from 10 to 20 per cent.

On some roads, under very favorable conditions, the cost of renewals and repairs to electrical apparatus has been but little below one dollar per day per car in actual operation. On other roads, under very favorable conditions, the cost of maintenance has been less than 25 cents per day per car.

A mean of the reports obtained from eleven roads in actual operation, under different conditions, shows a daily cost of operation of less than $2.50 per car, not including drivers and conductors. Experience has shown that it is well within limits to put the saving of electric over horse power at 25 per cent. In some cases a saving of 50 per cent has been shown. The Secretary of the Des Moines Broad Gauge Railway Company, under date of January 3, 1889, writes as follows: "The receipts from four cars operated electrically are four times more than five cars by horses."

3. Durability: —

The Washington road has been in operation for over six months. They now have seven motor cars and seven tow cars. The latter are double-deck cars, on which 160 fares have been collected on one trip. These cars are hauled around sharp curves, and up a 5 per cent grade, by two 10 horse-power motors. While the track was new it settled. A car left the track, and while it was being pried back one of the motors was injured mechanically. With this exception, not a single armature or field has been burned, and the gears show but trifling signs of wear. The road has operated without any repair shop, and practically without any repairs up to the present time.

At Lynn, Mass., a single car has been in daily operation since November 19th of last year. It runs 93 miles per day, and the 1.7 mile of track contains 11 curves and numerous grades, ranging up to a maximum of 12 per cent. The durability of the electrical apparatus, under such unusual conditions, has been remarkable.

4. Reliability: —

On the Lynn road above referred to, the single car has made its daily trips with but very few departures from the schedule. On one occasion the car axle broke, due to a flaw in the metal. On another occasion the belt slipped from the engine at the power station. Since the middle of February not a scheduled trip has been lost from any

cause whatever, nor has the car failed to run on time. No one can look at the daily record of this car, under conditions which would prevent horse car work, and doubt the reliability of electrical apparatus. On the Cambridge line of the West End Road the conditions are uuusually bad. During the month ending April 19th the schedule called for 5912 round car trips. Of these the electrical cars failed to make just four trips.

As the railway employes become more familiar with electrical apparatus, and learn more of the details of handling the cars, accidents, mishaps, and lost trips will grow fewer and fewer; but the records above referred to suffice to prove the reliability of the electric motor.

Storage battery cars are in operation on one road in the United States,— the Fourth Avenue line in New York city. Conduits have been built in several places. In San Jose, Cal., and in Denver, Colorado, they were complete failures. In Alleghany city, Penn., the conduit has operated with considerable success. In Boston it has not been a marked success. There are at the present time over one hundred roads in operation, or under contract, where the overhead wire system is to be employed. From this we may infer that the storage battery and conduit are yet in an experimental stage, while the overhead wire is a pronounced and demonstrated success. What the future of storage batteries and conduits may be no one can tell; but we all hope that the difficulties encountered may be overcome, as the storage system is unquestionably the ideal system.

The objections usually urged against the overhead wires are:—

1. They are dangerous, as they carry death-dealing currents.
2. They are eye-sores.
3. The poles obstruct the street.
4. They are in the way in case of fires.

Now, the railway wire should not be confounded with other electric wires. Arc and incandescent wires, telegraph and telephone wires, have simply to carry the current from the point where it is generated to the point where it is to be used; and so far as this purpose is concerned, they may be above ground or under ground. The railway wire, on the other hand, must have current taken from it every differential of an inch, from one end to the other. The wire must be bare, that the trolley wheel may be in constant contact. To

put this wire under ground, and to keep it properly insulated, is a very different problem from burying the other wires. The railway wire cannot be considered in the same category with other electric wires.

Now as to danger.

For railway work we use a constant potential generator, and the cars and motors are placed between the two conductors on the multiple arc system. One conductor, the overhead wire, runs out from one pole of the generator; the other conductor, the rail, runs out from the other pole of the generator. An electrical connection between these two conductors completes the circuit, and the current flows through the connecting material, whatever it may be. If it be the motors on a car, then the car moves; if it be a man, he receives a shock.

Each connecting material, be it car, man, wires, or whatsoever, receives a current of electricity which is absolutely and always determined by Ohm's law, that the current is equal to the electro-motive force or pressure divided by the resistance. The electro-motive force is always 500 volts. With several cars in operation the amperes of current in the overhead system, near the generator, may run as high as 180, but each car takes its own proportion, according to its resistance. The average resistance of a man is 4000 ohms. If he place himself in the circuit he will receive a current which is measured in amperes by dividing 500 by 4000, or in other words, a 500 volt current can only drive one-eighth of an ampere through the average human body. It would not make a particle of difference to the man whether the overhead wire he touched was carrying a current of 1 ampere, or 180 amperes, or 180,000 amperes. The effect, in his case, would be the same,— he would receive one-eighth of an ampere. Were this not true, then the whole multiple arc theory would be false, and electric railways, as at present operated, would be impossibilities. It would then make no difference, as to danger, whether one or one million cars were in operation on the line.

To make this matter plain to those unfamiliar with electrical terms, we may suppose the overhead wire to be a large pipe or main through which a pump (the generator) is forcing water. The rails, as electrically connected, form another large pipe through which the water is to be forced back to the station. Suppose the diameter of

these mains is 12 inches. If they are closed at the outer ends we may fill the overhead main, but after that no water can flow until we connect the two pipes. Now we will put in a one-inch pipe, connecting the upper main with the lower main, say 1000 feet from the pump or generator. A certain amount of water will flow through the connecting pipe, which amount depends upon its size — one inch — and upon the pressure of the water in the upper main. From the generator to the one-inch connecting pipe the same amount of water flows in the upper main as flows down through the connection,— no more and no less. Beyond the connecting pipe no water is flowing in the upper main.

Now we will put in a second connecting pipe 1000 feet beyond the first. For the first thousand feet we have twice as much water flowing as before. Half of it goes down through the first pipe. It is the same with every additional connecting pipe we put in until we reach the capacity of the upper main or the capacity of the generator to force water through it. By increasing the pressure we know that we could force more water through the one-inch connecting pipe, and so long as the pressure remains the same the quantity flowing through the inch pipe will be the same, whether the upper main be 12 inches, 12 feet, or 1000 feet in diameter.

The analogy to electric railway work is close. Electricity takes the place of the water, and the connecting pipes are electric cars, or it may be some unfortunate man placed where he ought not to be. He is only an inch pipe, however, and the pressure (500 volts) can only drive so much electricity through him.

The current for railway work has been fixed at 500 volts, as this is well within the safe limits. A shock from 500 volts is unpleasant, but not dangerous. No man, woman, or child has ever been killed, or even seriously injured, by a 500 volt current. The United States Senate had this question before them last summer. After a thorough investigation the District Committee unanimously reported that a 500 volt current is not dangerous. If there was any real question of its being dangerous we would use 400 volts or 300 volts. The objection to this, however, is that by reducing the voltage we must correspondingly increase the quantity in order to retain the same horse power, and an increase in quantity (amperes) means an increase in the size of the overhead wires, which is objectionable.

The danger limit to the electric current is probably about 1000 to 1200 volts.

As to the poles being eye-sores: I presume this is a question of taste. I have yet to find a single man, however, who refuses to acknowledge that when he went out to look for the objectionable overhead wires he failed to find what he expected. What was in his mind's eye was not over the street. A neat pole on either side of the street. A small galvanized steel wire connecting them at a hight of 20 feet, and suspended from these cross-wires a single copper wire over each track. You have no idea how free from objection such a structure is. You might cross an electric railway a dozen times without noticing the overhead construction.

The poles cannot obstruct the street, as they are inside the curb. They are just as much an obstruction to the sidewalk as lamp posts and awning posts are,—no more and no less. If the sidewalks be narrow, and permission can be obtained from the property owners, hooks or eye-bolts may be placed on the buildings, the cross-wires fastened to them, and the poles done away with entirely.

Every overhead wire is objectionable to the fire commissioners. The railway wire is less objectionable than any other, because there is but one wire, and this wire is in the middle of the street, away from the buildings.

If the single overhead working conductor is insufficient to carry the current necessary to operate the cars, it must be reinforced by feeder-wires. These feeder-wires may be insulated and may be placed under ground, the overhead wire may be divided into sections of three, four, six, or a thousand feet in length. At the ends of each section a cut-out or switch may be placed on the pole like a fire-alarm box, so that in case of fire the current may be cut out of the section or sections in the vicinity of the fire. The firemen would then have no difficulty in handling the wires, which in any event are easily cut by pliers with insulated handles. As ladders are usually raised parallel to the face of the building, rather than across the street, and as the cross-wires are 125 feet apart, it would be a very rare thing that the railway wires would be found to interfere at all with the operations of the fire department. As Prof. Thomson pertinently remarked to the insurance representative: "It will not be long before you will be taking power from these wires to put out your fires. It will not be long before we have electric-motor fire engines."

Charles J. Van Depoele and Leo Daft were the pioneers in the modern electric railway work in this country.

The first roads were built in 1884–85. The new motive power was, however, viewed with suspicion, and progress was slow until the Richmond road was built by the Sprague Company, in 1887–88. This road did much to popularize electric motors. The rapidity with which the horse is now going is shown by the growth of the railway business of the Thomson-Houston Electric Company, one of the several companies working in this field. In the spring of 1888 this company purchased the patents of the Van Depoele Electric Company, of Chicago. At that time there were some fourteen roads operating under the Van Depoele electric system. The first Thomson-Houston car was started at Crescent Beach, Mass., July 4, 1888. On the 1st of April, 1889, in less than nine months, there were 18 roads with 104 motor cars in operation, and 33 roads with 210 motor cars, under contract.

The reasons for this rapid growth are not difficult to ascertain.

The Americans are essentially a fast people. We live fast, and, unfortunately, we die fast. But as long as we do live, we go. Any time-saving device is gladly welcomed, and at once becomes popular. The limit of speed with horse cars is about 8 miles per hour. With electricity, the only limit is what we may fix as a safe speed. If horse cars are delayed, there is little or no chance of making up lost time. The reverse is true of electricity. With electricity we have rapid transit, and we can obtain it in a very simple and not too expensive way. Electric motor cars do not smoke or give off noxious gases, or make disagreeable noises. It is not necessary to run them in the air or under the ground, though they would run well in either position. They are safe, clean, fast, and reliable. They do not keep the street in an unclean and unhealthy condition. They do not take up as much of the street as do horse cars, for they have no horses. They are brilliantly lighted at night.

All of these qualities appeal to the public, and the verdict everywhere is favorable to electricity. The United States Senate and House of Representatives, in reporting on a proposed extension of the Washington road, said: "It is undoubtedly the best electric railway in the United States, and beyond comparison superior to any horse railway."

To obtain these advantages the public must aid the railways. The rails must be of sufficient weight and of such form as to best carry the increased weight, and stand the increased speed. Some form of girder rail weighing not less than 45 pounds to the yard is best suited to this work. The rail must be so placed as to be easily kept clean, and for this purpose should be slightly elevated above the surface of the street.

On the part of the railway companies, while the first cost is great, they can look forward to reduced operating expenses, a greater car mileage per day, and a great increase of traffic.

Electricity has undoubtedly come to stay.

MEETING 390.

Profit Sharing.

BY REV. N. P. GILMAN.

The 390th and annual meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, May 9th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the report of the Nominating Committee was read, and officers elected for the ensuing year.

The reports of the Executive Committee and Meteorological Committee were presented, and ordered placed upon the records. The President then introduced Rev. N. P. Gilman, who read a paper on "Profit-Sharing."

Mr. GILMAN said: I shall confine myself, this evening, to a practical view of my subject. The theory of wages is a very simple matter, so far as the division of profits between the employer and the employe is concerned. If his business is profitable, he can afford to

pay the current rate of wages, and the question then arises if he cannot make it still more profitable for his workmen and himself by dividing among them a portion of the profits he realizes. Will a proposition of this kind, made by a manufacturer to his men, have the effect of increasing zeal, economy, and carefulness among them to such an extent that his own share of the profits will be at least as large as the whole was before, or even larger? Experience, not theory, must be called upon to answer this question. If in a considerable number of thorough trials of the principles of profit sharing it results in an increase of the whole profits of the business, and the workman's bonus is not taken out of the average profit, but is an addition, then profit sharing is good sense and good business. If, on the contrary, under the system of a division of profits between master and man, the men are no more zealous, economical, and careful than under the simple wages system, if thus the resulting profits, so far as labor is concerned, are not greater than before, then profit sharing is obviously poor business and nonsense. Let us, then, at the outset, dismiss theorizing about a wages-fund or other chimeras, and let us equally dismiss the confident prophecies of business men or others who know just what workmen will do if offered a share in the profits of business. Prophecy as an avocation is properly held in very little respect today. For my own part I have as little regard for it when coming from the lips of a business man, about matters concerning which he is distingushed by a plentiful lack of knowledge, as when it falls from one of my clerical brethren who are following Mr. Edward Bellamy's will-o'-the-wisp, and are not only "looking backward," but are also looking down upon experience. The scientific temper is equally averse to the Philistinism of the business man who reads only his partisan daily paper, and the enthusiasm of the hasty reformers who propose to inaugurate their kingdom of heaven tomorrow or next year. Always "the next step," as Rev. Mr. Savage says, is the practically important matter. Because profit sharing is such a feasible next step, I commend it to men whose action must be ruled by the facts of the existing social order.

It is disorder, to be sure, which we see in the industrial world today. When the United States Commissioner of Labor gives us the figures in detail, to show that in this country there were in the six years, 1881–86, 3902 strikes, involving 22,304 establishments, and

causing an estimated loss to workmen and employers of nearly one hundred million of dollars, we may well suppose that some remedy for our industrial diseases is needed, a little more searching than arbitration, which is a good poultice but a poor regimen. Coming down to the bottom facts, what is the workingman's usual complaint? Is it that he does not get "his share" of the profits of the business? Allow that he is often mistaken as to the size of those profits, that he rates too low the importance of the executive ability which supplies him work and puts capital to use; that he often makes irrational and preposterous demands,— allow all this, and there yet remains a remnant of good sense in his argument.

Whether he is right or wrong, the one best way apparently to bring him to a realizing sense of facts is to admit him to some kind of partnership, which shall make him, to a limited extent, a sharer in the profits and the losses of industry. There is such a method of "industrial partnership" which is commonly known as profit sharing. It is the method of rewarding productive labor by assigning it a share in the realized profits of business in addition to wages. Profit sharing, as worked out today in practice by more than a hundred firms in Europe and America, involves no disturbance of the existing wage system. It is a supplementary feature, introduced in order to supply some of the plain deficiencies of the usual system of pure wages. The employer conceives the plan to be adopted in his own establishment; he assures his employes, at the beginning of the trial, that they shall receive the current wages; that the capital invested in the enterprise must then draw the usual rate of interest, and that suitable salaries for management must be allowed. Thus the three factors in production are to work on, as now, and the same provision must be made in the future, as in the past, for depreciation of the plant, the minor and running expenses, and a reserve fund.

If there remains, at the end of the year, a real profit, after all these expenses have been met, then the workmen shall be admitted to a share in it, instead of being left out of the calculation entirely, as they usually are, while the capitalist and the employe divide the profits. This workman's share the employer may fix definitely at ten per cent, for instance, of the surplus, or he may reserve the determination of the percentage until the end of the year. The principle is the important matter; there is great elasticity in the application,

according to the nature of the particular business. Now, what has been the result in the great majority of recorded instances where such an offer as this has been made? The effect has usually been that the employe, in the course of a year or two, if not sooner, begins to show some of the qualities of a man who has an eye for profit as well as for wages. If the employer points out to his men, as he should, the numerous items of waste and loss due to the lack of care on the part of the workman, they become anxious to save, because such saving is so much added to their bonus. They are more careful in the handling of the tools and machinery. They look after each other more sharply because of a common interest in securing good work. They realize more and more, as time goes on, that they are in a real partnership with their employers, and that they should work in some degree as if working for themselves. It is a very different thing from that wearisome platitude about the interests of labor and capital being identical. When the interest of the men in a particular shop is thus plainly brought into accord with the interest of their individual employer, strikes and other labor difficulties tend to disappear thoroughly from such an establishment.

While the future undoubtedly holds in it other labor problems which must be met and solved, the advocates of profit sharing may properly claim that of all proposed remedies for labor troubles it is the most practicable, that it has excellent credentials from the numerous firms that have tried it for a term of years, and that its obvious merits are such that a very wide and very thorough trial of it may reasonably be asked in order to determine its practical limitation. No sensible person claims that any one method of relief for labor troubles is universally applicable. Notwithstanding the repeated disclaimers I have made in my volume to the effect that "any attempt at a panacea" for existing discontent in the industrial world "is plainly irrational," a friendly critic in *The Nation* easily sees that I have not rid my mind "of the notion that it is in this way the discontent of the laboring class is to be met." Myself a professional reviewer of books for years, I know how hard it is to convince a reviewer that he is not better acquainted with the mind of an author than the innocent author himself. Even when we reviewers have to follow the African traveling custom of which Prof. Huxley somewhere speaks, and cut our noon-day steak from the ox on which

we ride, we feel that we are still superior to the poor beast! The labor problem, says the reviewer in question, is the problem of population. But I must assert once more that I have only attacked one side of the "wage question," leaving the other side of it, and the labor problem in general, and the population problem in particular, for better instructed persons to deal with.

To put profit sharing in another light: Here is a great industrial civilization, in which a large number of able and unwearied men are carrying on business with all the faculty they possess, under the keenest impulse of direct self-interest. They make a certain amount of profit here and abroad in a particular year. They keep it all to themselves. The workingmen are discontented, and strike, having no share as partners, in any sense, in the profits that are made. Industrial warfare is carried on to the immense detriment of masters and men. Suppose an employer consults the body of experience now open to him as to the advantage of allowing his men a percentage of the profits, and admits them to a closely limited industrial partnership. He soon brings into play new motives to action in the men, but precisely the same motives that he has most respect for in himself; they are aroused by the view of a possible profit in addition to a certain return in wages. The men discover in time what it is reasonable to expect, in a period of years, as an average bonus. They are taught, as no other method will teach them, that many of their ideas as to the ease and good fortune of a master's life are irrational. They receive a training in business which nothing short of some kind of partnership can give them. As the modern world becomes more democratic politically, it tends to become more democratic industrially. But this tendency toward equality will never, in my opinion, do away with the essential aristocracy of intellect in any sphere, least of all in the business world, which cannot be conducted on the town-meeting plan.

In the interests of employers as well as employes there is needed an improvement in the quality of labor. Such an improvement has been wrought out, on a limited scale, by the numerous firms in a great variety of industries whose experience I have summarized in my work on profit sharing. The change must begin with the more intelligent workmen and the more intelligent employers; the partnership principle will need to work from above downward, and take time

to produce its educational effect. I am neither a prophet nor the son of a prophet. I will not undertake, therefore, to predict the number of firms which here in the United States will be practicing profit sharing ten years from now. It would be, however, a singular phenomenon if, with such a recommendation from experience as its history shows, and with such an amount of favorable opinion as I have discovered from the able men whose positions make them impartial students of labor difficulties, profit sharing should experience an arrest of development, and go no further. The one need of the existing situation is information concerning the matter that can be relied upon. I have too much confidence in the shrewdness and the fundamental fair-mindedness of American employers of labor to suppose that they are all in the "pooh-pooh" stage of development themselves with respect to suggested modification of the wages system, or that the majority of them will remain in it. Men, indeed, easily forget how recent a phenomenon this system is in the development of industry. We are too apt, here as elsewhere, to consider our inherited habits to be the eternal laws for the universe. The wages system is not exempt from the force at work elsewhere adapting old institutions to the new needs of a growing humanity.

Profit sharing will not, at present, please the Malthusian; it will not satisfy the followers of Mr. Henry George, who declares that the "natural wages of the laborer is the product of his labor," and that "less than this it is a sin that he should be compelled to accept," the manager and the capitalist being considered unworthy of attention from their school. A simple share in profits will not seem of account in the eyes of the ardent minds who pine for nationalization of land and industry. But slow is "the unreasoning progress of the world," in Wordsworth's phrase; a little less slow is its reasoning progress, as, guided by experience, and determined to keep to the substantial world of fact, we put foot before foot, chiefly concerned that our next step shall be both forward and permanent. Such a step, and it is a long one for any large section of the industrial world, with its natural and proper conservatism, is the extension of the principle of industrial partnership to the highest grades of workingmen. The movement toward profit sharing has all the force of reasoned moderation behind it. That force becomes more confident of the rightness of its course as the body of favorable fact increases. The objection to a

trial of profit sharing rests for the most part on misapprehension and misinformation. The argument for it is simple and strong. It is a practical problem to be worked out by sagacious business men, who believe that success has its duties, and are not unwilling to be counted with Johns Hopkins's saying, "This wealth is my stewardship."

MEETING 391.

Gas Lighting by Incandescence.

BY PROF. WALDRON SHAPLEIGH, F. C. S.

The 391st meeting of the SOCIETY OF ARTS was held at the Institute, on Thursday, May 23rd, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Prof. Waldron Shapleigh, F. C. S., of Gloucester, N. J., who read a paper on "Gas Lighting by Incandescence."

Prof. SHAPLEIGH said: In these days of rapid changes and advancement we are apt to forget the beginning of many of our modern conveniences. Mankind first for artificial illumination depended on wood fires, pine torches, dried oily fish, and rush lights. Then the inventor first appeared, and lamps were introduced for burning crude animal or vegetable oils. One form of these lamps is still in use by miners. In ancient temples where for religious reasons or for convenience the lamps were never allowed to go out asbestos wicks were used. The tallow dip or candle is supposed to have been introduced in the second or third century; and from that time until the year 1800, when Carcel invented the mechanical lamp, but little advance was made. Although the Chinese had long been familiar with the use of coal, or more properly natural, gas, as they were not gas manufacturers, but obtained it when boring for salt by piercing coal seams,

and utilized the gas both for heating and lighting purposes. Experiments were not begun, however, in Europe until the latter half of the eighteenth century, with gas from coal; and in 1793 Murdock, an Englishman, erected the first gas works. About the same time gas from wood was used in a very small and experimental way in France, and oil gas in 1815. Gas was first used for street illumination in 1812 in London, and in 1815 in Paris. These dates are interesting, showing that, although a new country, we were soon to follow, for in Baltimore, though the first attempt was not successful, it was made so in 1821, in New York in 1827, and in Boston in 1822, or only sixty-seven years.

We have already grown discontented with it as an illuminant, as the public has been educated to a higher standard by the competition between electricity and gas light,— and this competition has and will lead to improvements in both. The electric light, by its steadiness, freedom from heat, convenience, and purity of color, has made a demand for similar advantages and qualities in the use of gas as an illuminant. Up to within a few years the work done has been in the line of improvement in the economy of manufacture and purity of the gas, increasing its illuminating quality by superheating or enriching with hydrocarbons, and regulating by governors, etc. Now attention is directed to obtaining from the gas its greatest heat, and using this energy to render non-combustible bodies incandescent, or properly lighting by incandescence.

The illumination from gas, as ordinarily used, proceeds from the liberation of the solid particles of carbon from the olefiant gas and rich hydrocarbons by the heat caused by the oxidation of the hydrogen at points in the flame when the supply of oxygen is not sufficient for both hydrogen and carbon, and by the combustion of the carbonic oxide. This heat renders these carbon particles highly luminous. These particles are themselves oxidized, and generate heat or energy which is lost. This is saved when the gas is completely oxidized, or converted into a heating flame, and this heat applied directly to an incandescent body. The lower the heat required to render this body incandescent the greater will be the economy in the use of gas and greater the amount of light produced.

That the energy is lost is very easily demonstrated. If the combustion of the gas is assisted, and rendered perfect by the aid of

oxygen fed into the gas jet under pressure, the maximum heat is obtained; and if this is now directed on a refractory body, such as lime or some of the oxides of the rarer metals, the maximum light will be obtained. When lime is used it is familiar under the name of the calcium light. This form of light is only adapted to special cases.

All connected with gas lighting, and there are more than a thousand gas companies, with more than a hundred millions capital in this country, are directly interested in lighting by incandescence. While it may lessen the quantity of gas consumed, though I think it has been demonstrated that where the price is lower the income will be about the same. Whether this is due to increased consumption or peculiarity of meter I am unable to say, though I think the former, for the public will take an increase of the light rather than a decrease in the bills. The advantages and quality of this light will enable the companies to compete with the electric light, which, could it be supplied cheaper, would cause some restless nights among the manufacturers of gas as now used.

This country has a large natural gas field. How large is not known, as it is being daily increased, and the territory extended by discovery. This gas in itself is not an illuminant, or contains but little illuminating power, but its great heat-giving power eminently adapts it for incandescent lighting.

So also water and fuel gas, made from anthracite coal. The low cost of supplying these two gases, and their already extensive domestic use, makes a practical form of an incandescent burner very desirable. Mr. James Dredge, editor of the "London Engineering," classifies what difficulties this burner must overcome and the requirements to make it successful as follows: —

1st. Existing fittings should not be interfered with, excepting so far as burners and their adjuncts are concerned; and no separate system of service pipes must be required.

2nd. The system must give a better and steadier light than the ordinary gas flame; in other words, the inducement to employ it must be obvious and decided.

3rd. The cost of new fittings and of altering existing ones must be moderate.

4th. The management of the system must be as simple as that

required for gas; facility of breakage or derangement must be impossible; and the duration of the lighting medium must be so great that the cost of renewals (which must be in any case insignificant) should be inappreciable.

5th. The consumption of gas must not be increased, but, on the contrary, a very marked saving, either in consumption or its equivalent in the increased light, must be secured.

6th. The combustion must be more perfect than of the ordinary gas burner, in order to reduce to a marked degree the objectionable and destructive effects of gas consumed in dwellings, *i. e.*, less heat, less vitiation of the atmosphere of the room, less smoke, less soot and unconsumed gas.

7th. The light obtained must remain constant, and not deteriorate with the use of the medium.

In going over the field to see what has been done we find, in 1876, J. D. Palmer, of London, filed a specification for the combination of a finely-woven wire-gauze cap of platinum, iridium, or other refractory metal, with a base through which atmospheric air and gas at ordinary pressure were admitted. These, mixing within the cap, produce on ignition sufficient heat to incandesce the gauze, the effect being increased by the addition of a central metal rod that was brought to and maintained at a very high temperature by the burning gas.

Reckenzaum and Redfield, in 1882, patented an apparatus for producing gas from a mixture of air and hydrocarbon, and a burner formed of a coil or other form of platinum or iridium gauze, to which the gas is led.

Thomas Cooper, of England, 1883, has also a form of lamp as above.

W. B. Wicken, of London, filed a specification, in 1883, for a regenerating gas lamp, in which the source of light was to be a spherical mass of loosely-compacted platinum wires suspended over the heat from a Bunsen burner.

Victor Popp, of Paris, in 1882 and 1884, secured two patents for wire-gauze incandescing cones.

J. S. Williams, of New Jersey, in 1882 secured a patent in England for what he terms a thermo candle. He impregnates or coats a gauze of any suitable material as a base or form for the deposition of metal or metal alloy, thereby obtaining an extended open surface for

the development of the light, with a comparatively small amount of surface to be heated; or metals possessing the greatest refractory quality can be spread over the surface as a mere film in thickness, and can be alloyed with a cover and coat of other material, such as oxide of magnesium, etc. The most important and perfected of the incandescent lamps or devices, where platinum or platinum alloys are used as the refractory material, is that invented by James Lewis, of London, and perfected recently by J. S. Sellon, and known as the Sellon lamp. It consists of a lengthened Bunsen burner, terminating in a cap or hood of platinum or alloy of platinum gauze. This is inclosed in an ordinary cylindrical glass chimney. Another form, known as the Star lamp, consists of a similar Bunsen burner in the form of an ordinary table standard base. The top of the burner enters the bottom of a glass globe, which is divided horizontally in its middle by an asbestos diaphragm, in the center of which a star-shaped opening is cut, which is covered by the gauze. The upper portion of the globe terminates in a chimney.

The two sections of the globe are secured by a suitable brass band and screws. The mixed gas and air passes into the portion of the globe below the gauze, and burns in and above the meshes of the gauze, rendering it incandescent. The radiant heat is far more perceptible than the ordinary gas.

In all the forms of burners so far mentioned the heat required to render the gauze hood or cone of metal incandescent is too great, while the wire or thin foil used for their construction soon burns out, or is in some way disintegrated after very short service. Under the microscope the metal seems to be deeply pitted and warty, and when in the form of wire it exhibits fine longitudinal cracks which, as the superficial alterations penetrates deeper, become more open, or, as it were, spongy, until finally, and this in a surprisingly short time, the wire completely disintegrates. Though iridium and platinum are very refractory metals, hoods made from them, under these circumstances, soon become too rotten for use.

Ch. Clamond, of Paris, in 1880 and 1882, patented a lamp in which he used a hood or reticulated cone of magnesia as the incandescing organ, which is supported above an earthenware burner, so constructed as to superheat the gas and air before ignition, and described in his patent as follows: —

"For the combustion of gas in this manner (*i. e.*, to obtain the greatest heat) the air on its way to the flame is caused to pass through a tube of refractory material, which is heated to a high temperature by jets of the gas playing against its external surface; and, in order that the air may be more thoroughly heated, the interior of the tube is divided by partitions having apertures through which the air has to pass in a zigzag manner, being subdivided into numerous streams directed against the heated sides of the tube. From the tube the heated air issues through small apertures and mingles with the ignited gas, producing a flame of intense heat, which, directed on refractory material, such as lime, causes incandesence."

These have been introduced into Paris to a very limited extent. The claim is one cubic foot of gas for five candles. A writer in a French journal, *L'Eclairage dans la Ville et dans la Maison*, states that the life of the basket is from twelve to fifteen hours.

The high price of this burner, $6.00, and baskets for renewals twenty cents, places this among the luxuries of incandescent gas burners. The claim of five candles per foot of gas I believe is too high, from a series of tests on several of these burners made in this country, with a consumption of 5¾ feet per hour, an efficiency of only 3¼ candles per foot, as a maximum was obtained, although they gave a fair light for fifty hours of continuous burning. This manner of burning is rather in their favor, as it prevents any danger of disintegrating by the magnesia or composition of the basket absorbing moisture and carbonic acid from the air, and thus slaking.

During the tests referred to the small holes in the heated earthenware became clogged with carbon deposited from the gas being decomposed before it could become oxidized by the air. This caused even more trouble than the burning out of the mantles, and ultimately terminated the experiment.

Chas. M. Lungren, of New York, patented in 1888 an incandescent burner, in which he uses a reticulated cone or basket, similar to Clamond's, made of magnesia, and supported over a form of Bunsen burner.

The heat required to render such a large quantity of material incandescent, as is necessitated by the construction of the hood or basket, prevents this form from ever becoming successful. The hoods must, in order to become incandescent, consist largely of magnesia,

and this too rapidly disintegrates and loses its light-giving properties, besides it rapidly volatilizes.

Two forms of incandescent devices have been invented applicable to water or fuel gas only.

One by Otto Fahnejelm, of Stockholm, in 1883, and consists of a double row of fine rods or pencils of magnesia, clamped in a metal holder, and suspended over the water gas as it issues from an ordinary bat-wing burner. The light is soft and steady, and the magnesia combs are said to last eighty hours. This form of burner has been more largely introduced here and abroad than any so far mentioned.

The other, the Stewart and Hastings, patented in 1888, differs from the above in that instead of rods or pencils small tubes of magnesia are employed, and these are in the form of a circle, resting on a horizontal pipe in the form of a ring perforated so that the gas jets are between the tubes; and the tubes are held in position at their upper ends by passing through a perforated disk, connected with the circular tube by means of a central support. The incandescing material being in the form of tubes, with very thin walls, are strong, and contain but little material to heat.

The last I have to describe is the Welsbach Incandescent Gas Lamp, and I will go more fully into this as it is the only one fulfilling the requirements previously mentioned for a successful burner, and as such the only one that is meeting with a general introduction in this country and abroad. It is the invention of an Austrian chemist, Dr. Carl Auer von Welsbach, of Vienna, who in 1886 put his researches into a practical form. His attention was first called, in 1880, to incandescent gas lighting by Prof. Bunsen, of Heidelberg, in whose laboratory he was then a student, as being the only economical and perfect method of utilizing the full energy of gas for illumination. He selected for his experiments the most refractory, and at the same time incandescing at the lowest temperatures, *i. e.*, the then rare earths. These possess the necessary qualities to a greater extent than any of the known elements. From these he made the mantle or hood. To give the required heat he employed an improved form of Bunsen burner. The lamp, as now introduced in this country, with the many changes made here, is as follows: —

Figure 2 is the Bunsen burner, consisting of a base into which the tube is screwed. Inside, at this point, is a disk perforated by three

FIG. 1.

FIG. 2.

Fig. 1. The complete Welsbach Incandescent Gas Burner.

Fig. 2. The Bunsen Burner and Air Shutter, as used with the Welsbach Burner.

fine holes, through which the gas enters the tube. The velocity of the gas passing through these holes draws in through the holes in the tube enough air to cause complete combustion, and thus the greatest heat. To permit of adjustment of the supply of air to the gas, a shutter shown in figure 2 is slipped over the tube.

In use the ordinary gas jet is unscrewed, and the Bunsen burner screwed on in its place. This is the only change necessary to adapt the lamp to any fixture.

Figure 1 shows the lamp complete. The brass gallery supporting the glass chimney, and inside an iron wire to which the mantle of

FIG. 3.

FIG. 4.

Fig. 3. The Welsbach Mantle before the cotton is burned out.
Fig. 4. The Welsbach Mantle ready for use.

incandescent material is suspended, has been placed over the Bunsen burner, and the lamp is ready for lighting. Inside of the brass gallery in the cup covered by the lower part of the mantle, and into which the upper end of the Bunsen enters, are placed two disks of wire gauze to prevent the Bunsen burner from "flashing back," or, more properly, the gas from igniting in the tube where it first enters and becomes mixed with the air.

Figure 3 represents a mantle in its first stage of manufacture, and consists of a tubular piece of webbing knitted by machinery, from the best quality of cotton thread. This is important for the reason that the mantle, when the cotton is burned out, will be an exact duplicate in oxides of the rare earths. Not only will the loops and twisting of the thread be reproduced, but even the fuz or individual fiber; and to show how refractory these earths are, these minute fibers exhibit no signs of fusing or volatilizing, even after hundreds of hours of burning. A strong and well-made thread, for the above reasons, it can be easily seen, will be required for these mantles. It gives to the completed mantle the mechanical strength of construction it possesses itself. The webbing, after being cut into proper lengths, is thoroughly washed, dried, and dipped into a solution of the rare earths, and again dried. A small piece of platinum wire is sewed into the upper end, by which it is secured to the iron wire support which holds it in place over the flame. After attaching it to the support it is formed into the desired shape of the finished mantle or hood, and the cotton burned out over a Bunsen flame. Any wrinkles or imperfections in shape are at this stage pressed out by means of a steatite pencil, for it is now pliable, and can be easily formed, stretched, etc. It is now as it is shown in figure 4, ready for use; or, if to be shipped, it is dipped into a solution of shellac or similar material to prevent breakage. This burns off the instant the lamp is first lighted.

The mantle in ordinary use for coal gas is $\frac{9}{10}$" in diameter by four inches long, or containing nearly twelve square inches of surface. Yet it weighs but six grains, one half grain to the square inch, or a pound of the rare oxides used in its construction would cover 14,000 square inches of surface. This clearly shows how little material has to be heated to produce incandescence. This is the great point of success in this system and where the energy of the gas is utilized. Yet these oxides, even while in such an attenuated form, are practi-

cally infusible. A mantle has been burning continuously in Indianapolis for over 3600 hours, and is still giving good light.

It has been suggested by many chemists and mineralogists that the lamps cannot be made in any quantity, owing to the use of the rare earths, on which its success so largely depends, existing in nature in such limited quantities, the supply would soon be exhausted. At first this looked serious, but on investigation new fields were opened up, and these earths were found to be only relatively rare. In North Carolina alone contracts can be made for the delivery of not only tons, but hundreds of tons, of zircon crystals, and this too at only a fair mining profit. These remarks apply to the mineral monazite, which contains all of the rare earths entering into the mantle, namely, zirconium, lanthanum, cerium, neodymium, thorium, and yttrium.

Monazite has recently been found in unlimited quantities as river and seashore sand, on the coast of Brazil, and may be collected without mining. A brief description of the composition of these mantles, and the action of the different rare oxides when submitted to heat, may be interesting. Zirconium oxide alone cannot be used, as the mantle is too rigid, shrinks, and gives but little light, which is white in color.

Lanthanum oxide alone, while it gives intense white light, soon unites with moisture and carbonic acid, and disintegrates. Together, however, in the proper proportions, they give an excellent mantle, producing a perfectly white light. The addition of neodymium, cerium, or yttrium oxide produces a yellow light. Erbium, holium, and thulium oxides, a green light. Thorium oxide alone is similar to zirconium, and gives a white light; and when mixed with lanthanum and zirconium oxides, it gives a white light. Yet thorium and lanthanum oxides will give a yellow light.

Thorium and lanthanum oxides are both pure white, yet when heated together give a brown compound, probably a salt.

Neodymium oxide an orange light, changing to pink.

Scandium and terbium oxides a fine white light.

Yttrium and lanthanum almost white. The addition of zirconium produces a yellow; yet with yttrium and zirconium alone the light is almost white. All of these oxides incandesce at a very low temperature, and are refractory, both singly and when united.

For making the fluid with which the mantle is saturated any of

their soluble salts may be used, if the acid can be driven off by heat. The nitrate is well adapted, as it also assists in burning the cotton.

In the mantle zirconium and thorium oxides may be regarded as the support or skeleton, and the other rare oxides added for the purpose of producing incandescence, to change the quality of the light, or to add additional strength.

Absolute cleanliness must be observed in every detail in the manufacture of the fluid and mantles. In the fluid the faintest traces of elements foreign to it can readily be preserved in the hood, and its manufacture requires the most careful supervision. The process is a long one, as it requires from six months to a year to bring the ores into the form of pure and finished salts, ready for solution. This fluid, as well as the mantles, are now being manufactured in this country, at Gloucester City, N. J., where the company have extensive works.

Working these rare minerals, semarskite, cerite, zircon, monazite, etc., in such large quantities, has led to many discoveries, and to the separation of new elements yet to be named, their properties investigated, and the one separated from the other. At present they hold the unique position of being by-products.

Dr. Auer von Welsbach, in his researches, succeeded in separating didymium, a long-discovered and so-called element, into two elements, which he named praseodymium and neodymium. The latter is largely used in the manufacture of the mantle.

The incandescent light produced from these rare oxides possesses great actinic power. Mr. George G. Rockwood, photographer, of New York, succeeds in taking excellent portraits in from four to ten seconds, in an ordinary gallery, with twenty-five small-sized burners, equal in every respect to those taken by daylight.

Regarding the practical application of the Welsbach lamp it has now been so perfected that it can be used with coal, water, fuel, gasoline, and natural gas with not only good but remarkable results, as to steadiness, color, and quantity of light. The average life of the mantle, which can readily be renewed, in ordinary use, is about four hundred hours, or three to four months. The color can be varied to any degree, from pure white to an intense orange.

It can be readily attached to any existing gas fixture. The small quantity of gas consumed throws off but little heat. In fact, the

hand can be placed without discomfort ten inches above a twenty-five candle-light lamp. The perfect combustion of the gas vitiates the atmosphere far less than other burners, as no unconsumed gas escapes. It has been stated that the light from these burners does not penetrate as far as ordinary gas light. This may be due to two causes. The purity of color we have not become accustomed to. If the experiment be made, one will find they can read at a greater distance, and with greater ease to the eyes, by this light than with any ordinary gas burner, though it may be apparently giving out more light. And the other cause is that the burner, being new, is steadily looked at and examined, even close to, until the eye becomes affected by the intense light, then, on turning away, the room appears dark.

Persons acquainted with the efficiency of gas as ordinarily used, until they experimented with the incandescent system, may doubt the high figures claimed for these burners. With natural gas an efficiency of twenty candles per foot of gas can be obtained; and with enriched water gas, under ten inches pressure, twenty-five candles per foot of gas, or an ordinary lamp burning six feet per hour of this gas, will give one hundred and fifty candles.

The following are, however, the results of tests made of Welsbach lamps by well-known gentlemen, being widely-known experts in matters connected with light and illumination.

DR. CHARLES M. CRESSON, Analytical Chemist, Philadelphia.

BURNERS.	Cubic Feet of Gas Consumed Each Hour.	Actual Candle-Power.	Number of Candles for Each Foot of Gas Burned.	Value of 1000 cu. ft. of Gas in Pounds of Spermaceti.	Economic Ratio.	Relative Cost for Gas for Equal Lights.
Standard Argand, City Test	5.00	18.4	3.68	63.1	1.00	$1.00
Small Welsbach............	2.50	19.0	7.60	130.2	2.06	.485
Large Welsbach	5.25	54.0	10.28	175.8	2.78	.36

Gas Pressure at Point of Ignition in Inches.	Consumption per Hour in Cubic Feet.	Actual Candle-Power.	Value of Each Cubic Foot in Terms of Standard Candle.	TEST MADE BY —
1.20	....	23.73	....	PROF. CHARLES F. CHANDLER, PH.D., School of Mines, New York.
1.20	2.85	23.71	8.32	
0.80	2.55	23.00	9.00	
0.96	2.65	30.02	11.29	
1.01	2.75	30.00	10.91	
1.01	2.25	25.5	10.8	DR. HENRY MORTON, President Stevens Institute of Technology, New Jersey.
0.90	2.10	25.5	12.1	
0.80	1.95	24.0	12.3	
1.00	2.30	23.0	10.0	
0.85	2.45	24.0	9.8	
0.95	2.75	33.0	12.0	
0.80	2.47	29.0	11.7	
.60	2.14	17.01	7.94	L. CALVERT FORD, U. S. Inspector of Gas and Meters for the District of Columbia, Washington.
.70	2.19	18.42	8.41	
.90	2.78	22.65	8.14	
1.00	2.82	24.11	8.54	
1.30	2.92	24.95	8.54	
.60	2.05	18.96	9.25	DR. WILLIAM WALLACE, F.R.S.E., F.I.C., F.C,S., Public Analyst, and Gas Examiner for the City of Glascow.
.70	2.20	21.00	9.55	
.80	2.42	21.90	9.05	
.60	1.95	19.02	9.75	
.70	2.10	20.75	9.88	
.80	2.30	21.19	9.21	
.90	1.85	18.40	9.94	
1.10	2.02	21.60	10.69	
1.30	2.20	22.60	10.27	
.90	2.20	18.6	8.1	CONRAD W. COOKE, London.
.90	2.40	17.5	7.3	
.90	2.55	19.5	7.6	
1.25	2.36	20.0	8.5	
1.25	2.25	19.0	8.4	

MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

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CONTENTS.

NOTICE.

The Society of Arts, established in conformity with the plan of the Massachusetts Institute of Technology, as set forth in the act of incorporation, April, 1861, held its first meeting on April 8, 1862.

The objects of the Society are to awaken and maintain an active interest in the practical sciences, and to aid generally in their advancement in connection with arts, agriculture, manufactures, and commerce.

Regular meetings are held semi-monthly from October to May, inclusive, in the Institute Building; and at each meeting communications are presented on some subjects germane to the objects of the Society, as stated above.

The present volume contains the abstracts of the communications made during the year ending October 1, 1890, most of the business portions of the records being omitted.

The thanks of the Society are due to Capt. A. H. Russell, for the loan of the electrotypes used in illustrating his paper on Magazine Guns; to Col. E. H. Hewins for those illustrating his paper on Storage Batteries; to the Electrical Engineer for those illustrating Prof. Thomson's paper on "Experiments with Alternating Currents"; to the Engineering and Building Record for those illustrating Mr. Woodbridge's paper on The Heating and Ventilating of the new Engineering Building.

For the opinions advanced by any of the speakers the Society assumes no responsibility.

LINUS FAUNCE,
Secretary.

Boston, Sept., 1890.

THE ENGINEERING BUILDING.

PROCEEDINGS OF THE SOCIETY OF ARTS

FOR THE TWENTY-EIGHTH YEAR.

MEETING 392.

*Biological Water Analysis.**

BY PROF. W. T. SEDGWICK.

The 392nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 10, 1889, at 8 P.M., Hon. J. A. Dresser in the chair.

After the reading of the records of the previous meeting, the Chairman introduced Prof. W. T. Sedgwick, of the Institute, who read a paper on "Biological Water Analysis."

Prof. SEDGWICK said: A biological analysis of water, strictly speaking, is an impossibility. Water may be analyzed chemically and resolved into its components, hydrogen and oxygen, but a biological analysis of water is an impossibility, because water is absolutely lifeless and inorganic. By a chemical "water analysis," however, the chemist does not usually mean the analysis of a portion of pure water, but only a chemical examination of the substances dissolved in, or carried by, the water. In precisely the same way a biological "water analysis" is understood to be simply *an examination of the organisms present in a particular portion of water.*

The biological analysis of a water must deal with all the organisms which can be detected therein; but inasmuch as the coarser water-dwellers — the fishes, the frogs, the snails, the water-weed, etc. — are seldom collected in a sample for water analysis, there are usually present only the very small, and often quite invisible, organ-

* Revised from an address published in the Journal N. E. Water Works Association, September, 1889.

isms which may nevertheless be exceedingly numerous. Practically, therefore, the biological examination is directed to the inconspicuous forms of life, which often swarm in waters, even in those used for drinking. Taken as a whole, these organisms are known as the "microörganisms," and form a vast group of living things, some of them nearly, and some of them quite, beyond the vision of the naked eye. In dealing with the microörganisms in a sample of water, or in a water supply, the coarser organisms must by no means be neglected; but the biological analysis of water as at present conducted is concerned especially with the microörganisms; and in the present paper no great departure will be made from the prevailing point of view.

Microörganisms are of two different kinds, and must be studied in two very different ways. Although all might perhaps be described as "microscopic" in size, those in one group are so much smaller than those in the other as to be almost smaller than "microscopic." These smallest microörganisms are the bacteria; and, although they may be seen by the help of the microscope, and, indeed, can be seen individually in no other way, they cannot be satisfactorily studied — still less counted — by the microscope alone. These organisms — the bacterial — are therefore detected and chiefly studied by the method of "cultures," otherwise known as "Koch's method," which I have already had the honor to describe and demonstrate at a meeting of this Society some two years ago. Of the bacterial microörganisms I shall speak tonight only incidentally, although within that time our knowledge of them and of their doings has been steadily advancing.

On this occasion I desire rather to turn your attention to the second division of the microörganisms, the microscopical. This includes all microörganisms except the bacterial, and is separated from that group by the fact that while the latter require for their satisfactory study the employment of "cultures," the microscopical microörganisms may be detected, counted, and pretty fully studied by the microscope alone.

In a summary fashion the relations of these groups may be shown as follows: —

MICROÖRGANISMS. Organisms, either plants or animals, too small to be studied with the naked eye.	MICROSCOPICAL ORGANISMS. Not requiring special "cultures." Easily studied with the microscope. Microscopic in size, or barely visible to the naked eye. Plants or animals. BACTERIAL ORGANISMS. Requiring special cultures for their satisfactory study. Difficult of study with the microscope, because almost sub-microscopic in size. Plants.

The bacterial microörganisms include the bacteria, as well as some yeasts and moulds. The microscopical microörganisms include a great variety of animals, such as minute entomostraca, like Cyclops and the water flea; various worms and wheel-animalcules; sponges and the fresh-water Hydra; infusoria, rhizopods, and such like; and among the plants, the diatoms, algæ, fungi (excepting those already mentioned), and the so-called "blue-green algæ." Beside the bacteria these forms are mostly of giant size, and hence may be seen and studied with comparative ease by the aid of the microscope alone.

I am the more anxious to urge upon your attention the microscopical microörganisms since it is with them that some of the more recent progress has been made in the biological analysis of water. Furthermore, it is in this field, in all probability, that some of the most interesting developments of the next year or two will be found. These are the organisms that often pave the way for the bacteria in water, and possibly therefore for the germs of disease. These are the organisms which are, in large measure, the source in water of the "organic nitrogen" (or albuminoid ammonia) of the chemists; the organisms, responsible in large measure, for odors, tastes, and turbidities in waters, either directly by their own activity, or indirectly by amassing organic matter, and eventually surrendering it as putrescible food for the more destructive bacterial organisms.

As long ago as 1850 Dr. Arthur Hill Hassall made a microscopical examination of the water supply of London, perhaps the first ever scientifically made anywhere, and, in discussing his results, wrote afterwards as follows: * "The deleterious properties of impure water depend, for the most part, on their *organic impurities.*

* "Food and its Adulterations," p. 55, London, 1885.

"Until very recently chemists did not, in general, attach sufficient importance to these organic contaminations, and in most of their analyses we find the different kinds of organic matter, vegetable and animal, living and dead, all lumped together and included under the word 'traces.' . . . Indeed, chemistry is but ill-adapted to investigate the nature of these organic matters; it gives but a very rough estimate only of their gross amount, and does not discriminate, as we have said, the animal from the vegetable, the dead from the living, and tells us nothing about the families, genus, and species to which the numerous living productions contained in impure waters severally belong, or of their habits and modes of life," etc.

For twenty years after Dr. Hassall's day his work remained almost alone. In 1870, however, Prof. Cohn, the biologist, of Breslau, in an extremely suggestive paper on the "Microscopical Analysis of Well Waters," perceiving, perhaps, better than anyone else has yet done the profound significance of such studies, wrote as follows: * "There is no doubt that microscopical examinations of drinking-waters, properly conducted, will strengthen and perfect the chemical examinations at the most essential points, and that they only will give us information upon certain questions which the reagents of the chemist cannot answer."

As if to justify his assertion, Cohn immediately proceeds to compare the results of chemical analyses with his own observations of corresponding microscopical conditions, and, as might have been expected, with interesting results. There is even here, however, no prolonged comparison of chemical with biological results, and hence no such fertile outcome as might have been attained.

After Cohn's paper we find nothing so suggestive up to the present day. It stands alone, so far as I know, in a serious and enlightened endeavor to coördinate and render mutually helpful chemical and biological data. With this one brilliant exception, little progress has been made in the interpretation of chemical and microscopical analyses of water (though of the former vast numbers have been accumulated), simply, I believe, because chemists, on the one hand, have been content to name the most complex and the most important substances in their analyses "organic matter," therewith

* "Beiträge zur Biologie," I, 109.

resting satisfied; while biologists, on the other, instead of seeking a simple explanation for the presence or absence of organisms, or endeavoring to learn their chemical significance, have too often dissipated their energies in struggles to classify those organisms which they could name, and to name those which they could not classify. Doubtless, also, the rise of bacteriolgy, soon after the appearance of Cohn's paper, with the intense interest which it aroused, did much to distract attention from the microscopical microörganisms, and to fix it upon the bacterial. But even concerning the bacterial microörganisms interest has been thus far principally medical. The discovery that infectious diseases may be propagated in drinking-water caused general alarm. Most bacteria, however, are not disease germs; and yet they are scarcely less interesting on that account, for by their presence they always signify something, and in their absence are hardly less conspicuous. Bacteria are fungi; that is, they are not green with chlorophyll, and, consequently, since they cannot build up food for themselves from mineral matters, as they might do if they had chlorophyll, they are obliged to live upon ready-made foods. If, then, a drinking-water contains bacteria, living and thriving, there is no escape from the conclusion that there is or has lately been ready-made food in that water. Well waters usually contain few bacteria; and this we would expect from their poverty in ready-made food,— which is only another name for some kinds of organic matter. River waters usually contain numerous bacteria, and ready-made food is generally there in the shape of organic matter of one kind or another. Now, it is precisely this ready-made food that the bacteria must live upon, and which they oxidize eventually to mineral matters, that the larger, microscopical, microörganisms abundantly produce. Moreover, the microscopical organisms not only pave the way for bacteria, they often themselves become serious nuisances in reservoirs and lakes used as water supplies, by giving rise to extensive "growths" which, either during their development generate directly odors and tastes, or during their decay support a prolific host of bacteria, thus generating indirectly turbidities or odors which make the water disgusting and unfit to drink. It is somewhat remarkable that while the importance of these organisms and of their accurate study has long been recognized, no satisfactory method has hitherto been devised for their study. Up to the present time the best methods have made no pretensions to be

quantitative, and microscopical examinations of water have been usually directed to the sediment obtained by letting a given sample stand for a longer or shorter time. The suspended matters have thus been more or less completely disregarded. Macdonald, in England, and Tiemann and Gärtner, in Germany, have no other methods to propose.

By straining through cloth a known amount of water, and afterwards detaching the organisms held back by the cloth upon a slide, where they could be approximately enumerated, the biologists working for the Massachusetts State Board of Health made a decided step in advance. Mr. A. L. Kean, working under my direction, has introduced a still more valuable method in the use of a sand-filter, and the subsequent quantitative examination of a thousandth part of the whole, in a ruled cell holding one cubic millimeter. Still more recently I have myself constructed a counting chamber, so arranged that a cubic centimeter, or more, of water may be examined directly, or, in case the organisms are few, the entire mass of sand and organisms left by filtration of a known amount of water (usually 100cc.) can be evenly distributed on a glass plate, then viewed with a moderately high power, and the organisms studied and enumerated with considerable precision. A full account of the various methods will appear in the forthcoming report of the State Board of Health of Massachusetts. At present I will only state that this one consists, first, in the *concentration* (if necessary) of the organisms in a large amount of water into a small amount, so that they may be readily scrutinized. This is done by filtration through a short column of fine sand in a narrow-stemmed funnel, the sand being supported upon a platform of the finest wire-gauge cloth. To secure the second point (the *enumeration*) the sand and organisms are washed down by distilled water into a shallow chamber or ruled cell one inch wide and two inches long, bordered by brass strips one-quarter inch high, firmly cemented to the slide. This counting chamber is so divided by the ruled lines that it contains 1,000 squares each $\frac{1}{25}$ inch on the side. The squares, therefore, nearly or quite fill the field of a low power objective, such for instance, as the B. B. of Zeiss. By the selection of representative squares it becomes possible, provided the organisms be evenly distributed, to estimate with considerable precision the total number of organisms upon the plate. In practice 20 squares are

usually counted and the sum obtained is multiplied by 50, thus giving the amount in 1,000 squares, *i. e.*, upon the whole plate. The sand may, after some practice, be easily neglected, and does not interfere. In the choice of the special arrangement of ruled lines, and especially in the patient construction of several finished plates by means of the dividing engine, I have been very greatly aided by my friend and former pupil, Miss C. A. Woodman.

From my results it appears that a teaspoonful of drinking-water often contains from twelve to fifty microscopical microörganisms, and may sometimes contain thousands. Indeed, they often far outnumber the bacteria, as, for instance, in the Newton reservoir, where, with 1,602 microscopical, only 6 bacterial microörganisms were found in a cubic centimeter of water. In this connection I may mention a curious result which was disclosed by an application of the method to the Newton water supply. Water was drawn from the tap in the railway station at Newton Highlands every morning, excepting on Sunday. On Mondays the numbers were observed to be very high, reaching into the thousands per cubic centimeter, while during the rest of the week they barely reached hundreds. Inquiry disclosed the fact that on week days water is pumped from the filter-basin directly into the service-pipes. On Sundays the pumps are not run, and the pipes are filled from the reservoir. The reservoir water, however, is much less pure than that drawn directly from the filter-basin; and this fact became immediately and strikingly apparent by the examination of a sample collected early on Monday morning, before the pipes had been filled from the filter-basin.

It may fairly be claimed, I think, that we now possess a simple, convenient, and effective method for the enumeration and study of the microscopical microörganisms. There is no doubt that this is a step forward in the biological analysis of water, which must henceforward include microscopical as well as bacterial examinations.

As the result of his own studies upon drinking-waters, Cohn, in the paper already referred to, laid down certain generalizations that do not seem to have attracted the attention which, if true, they should have received. For example (*l. c.*, p. 113): "We may divide the organisms in drinking-water [wells] into three categories, which correspond to different degrees of purity of the water:—

"1. Diatoms and green algæ indicate a water to which light has had access, and one poor in organic matter.

"2. Certain of the larger infusoria, especially the ciliated forms, feed on these algæ; while upon both the infusoria and the algæ feed —

"3. Entomostracans, like Cyclops and the water-flea, worms, such as Naids and rotifers, and insect larvæ."

The presence of these last scavengers-in-chief Cohn does not regard as inconsistent with the purity of the water. He considers it to be the function of the rhizopods, carnivorous infusoria, rotifer vulgaris, mites, and the water-bears, to devour solid or undissolved bits of organic matter; and of the mouthless infusoria and the bacteria to flourish upon dissolved organic matters. The latest German work upon this subject (*Untersuchung des Wassers*, Tiemann und Gärtner, 1889) does scarcely more in this direction than quote the above remarks of Cohn, and adds, "At the present time more stress is to be laid upon the quantity than upon the quality of the microscopic organisms."

In my opinion, it is in working out precisely such inter-relations and inter-dependencies of the microörganisms as are suggested by Cohn that we are now making real progress, and are likely to advance in the near future. It is self-evident that such laws, if firmly established, must become of the greatest scientific and practical value to all concerned in the use and supply of wholesome drinking water.

It is necessary, however, to go one step further. The protest of Dr. Hassall, quoted above, against the use by chemists and others of the indefinite term "organic matter" has lost none of its force by the lapse of time. On the contrary, the term thus used is less defensible than ever, and the time is gone by for students of water supplies to be satisfied if in reports of chemical analyses they find "the different kinds of organic matter, vegetable and animal, living and dead, all lumped together." Recent investigations show that such terms as "nitrates," "nitrites," and "free ammonia," have a definite meaning in important biological conditions.

Finally, it is not too much to affirm that, if it ever existed, the time is gone by when either a microscopical examination alone, or a bacterial examination alone, will suffice to base a professional or expert opinion of water upon. And furthermore, it is becoming clearer every day that an opinion of a water based upon chemical observation alone

(and, above all, upon a single analysis) is no longer a complete scientific opinion. A water analysis henceforwards must be three sided, viz., chemical, bacterial, and microscopical; and even then the conditions of the origin and of the neighborhood of the source of the water must be included as factors of equal importance. The standard of water analysis has of late appreciably risen, and reports of "water analyses," if they are to fullfil the conditions imposed by the most recent progress, must include three different examinations, as follows: —

I. ENVIRONMENTAL, *i. e.*, a more or less complete study of the source of the water, together with observations of the surroundings, and investigation of specimens unquestionably normal, from the vicinity.

II. CHEMICAL, *i. e.*, the usual chemical analysis, with special attention, however, to the state of the nitrogen present.

III. BIOLOGICAL, *i. e.* (1), *Microscopical*, viz., a determination of the number, the species, and, as far as possible, the conditions of the larger microörganisms present; as well as of the masses of *débris*, etc.

(2) *Bacterial*, viz., a determination of the number, and, as far as possible, of the species of the living bacterial organisms present.

MEETING 393.

The History and Theory of Cohesive Construction as Applied Especially to the Timbrel Vault.

BY MR. RAPHAEL GUASTAVINO.

The 393rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, October 24th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting and the election of new members, the President introduced Mr. Raphael Guastavino, of New York, who read a paper on "The History and Theory of Cohesive Construction as applied especially to the Timbrel Vault."

Mr. GUASTAVINO first took up the history of cohesive construction, and showed by numerous examples that this construction was very ancient, and was not any particular invention, nor originated by any determined civilization, but was only the fruit of necessity. It reached the height of its splendor in the middle ages and gradually disappeared in the same proportion that modern civilization and the Renaissance approached. This decline was mainly due to the fact of the disuse of the hydraulic mortars of the Romans, Arabians, and Byzantines, and that the art of manufacturing these materials which constituted the base of their cohesive construction was lost.

The first time that cements were generally used in modern days was from 1845 to 1850. From this date commenced the renaissance of "cohesive construction."

The speaker said: The works of this character that I have constructed in Spain; as, for instance, the manufactory of Battló, in the Corts de Sarria, where there are employed two thousand people with one thousand looms and 64,000 spindles, the other manufactories of Vidal, Muntadas & Co., and the woollen manufactory of Carreras, and the glass kiln of Cassademun with one arch of sixty-five feet span, with only ten-inch walls, and the cupola of the theatre of the town of Vilasár, of sixty-one feet span, are all permanent and durable buildings, the arches of which were built having the first two courses of plaster and the others with cement, representing 50 per cent of the construction with plaster, as I used in my first work in this country, where we knew that the excess of plaster was dangerous, if the walls and rods were not stout enough to resist the expansion. In some cases the risk and danger caused by the irregularity of the materials was so plain that the workmen were afraid, compelling me to remain in the works to inspire confidence and success.

The progress in Spain, particularly in Barcelona, in the special construction that we now have under consideration, was due to the studies and teaching of the professors who were debating for several years how to improve their respective specialties and the way to

obtain new practical systems of construction, knowing the fact that the improvement of the material required a change and improvement in the construction, but their noble aspirations were restricted, having no facilities, and it was necessary to satisfy themselves by recommending the theories of Vicard, about the use of cements, and other applications well founded.

Nothing was done about investigating these structures to which I have referred, and no coefficients were derived. This only can be obtained when we can depend upon the materials with mathematical regularity and with powerful apparatus for determining their reliability. In countries like this, where we can find more than twenty guaranteed brands of quick-setting Portland cement of different degrees, and where clay can be used for those constructions with advantage, and where we have regularity of manufacture, and finally in a country where we have powerful apparatus, coefficients can be obtained, as we have been doing for the past five years.

From these special advantages it seems that these works have culminated in the United States, taking a natural stand in New York and Boston, with specimens that have no rivals in any part of the world for lightness and resistance.

Cohesive construction differs from "mechanical construction" or the gravity system in that the latter is founded in the resistance of any solid to the action of gravity when opposed to the solid. From these conjunctive forces, more or less opposed to one another, the result is the equilibrium of the total mass, without taking into consideration the cohesive power of the material set between the solids, while the former has for a base the property of cohesion and assimilation of several materials, which by a transformation more or less rapid resembles Nature's work in making conglomerates.

The materials employed in the construction by gravity only require the physical quality of hardness; for the "cohesive construction" the materials must not only have proper physical conditions, but it is absolutely necessary to take into consideration the chemical properties of the substances employed.

Mr. Guastavino then had two arches of about 4½ feet span constructed before the audience in the same way they are being made in the new Public Library on Copley Square. The centers are ordinary boards cut to the proper curve, on which is laid a course of bricks or

tiles about 12″ x 6″ x 1″, the joints being of plaster of Paris. On the completion of the first course the centers are removed. The second course is laid in Portland cement, breaking joints with the first course, as is also the third course. The whole, after it is thoroughly set, forming a solid arch.

MEETING 394.

The Kriegsspiel as Practiced in America. Its Object and Place in Military Science, and its Relations to Military and Naval Manœuvres.

BY MAJOR W. R. LIVERMORE.

The 394th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, November 14th, at 8 P.M., Mr. John C. Ropes in the chair.

After the reading of the records of the previous meeting and the election of new members, the Chairman introduced Major W. R. Livermore, U. S. A., who read a paper entitled "The Kriegsspiel as Practiced in America. Its Object and Place in Military Science, and its Relations to Military and Naval Manœuvres."

Major LIVERMORE said: Kriegsspiel in its present form is a device by means of which military operations are represented upon a map, the troops engaged being indicated by movable blocks. The movements are made, and the losses and other results of the conflict are determined, in accordance with established rules, which are designed to conform as nearly as possible to the conditions of actual warfare.

It has long been apparent that a faithful representation of military movements might form the basis of a most agreeable recreation, while affording at the same time an opportunity for students of mili-

tary science to put in practice the principles and maxims which have accumulated in great numbers in the text-books.

The Kriegsspiel invented by Herr von Reisswitz, and elaborated by his son, an officer of the Prussian artillery, has met with favor among the Germans since the early part of the present century; and now that this indefatigable people has applied to the art of war the same exhaustive and systematic study that has proved so efficient in other branches of scientific inquiry, many of the results of its labors have become embodied in this game.

Outside of Germany for a long time the game was regarded with little favor. After the war of 1866, however, it was cultivated extensively in Austria, and the war of 1870 opened the eyes of all Europe to its importance. In the United States it has been practiced to a limited extent since 1867, and its popularity has increased with the reputation of the Germans as a military nation. It is now practiced extensively in Russia, Italy, France, Belguim, and elsewhere.

The Kriegsspiel is played upon a topographical plan, with small blocks representing the troops, which are proportioned to the scale of the map, occupying as much space upon it as the troops would occupy in the field. These blocks are moved simultaneously, under the direction of an umpire, and at rates proportioned to the mobility of the different arms which they represent.

When the position of the blocks indicates that the hostile troops are within sight and range of each other, they are supposed to open fire, if the players desire it, and in this case it becomes the umpire's duty to decide the result upon the basis of experience. The rules of the game explain to him how to estimate the loss from this fire; for example, it may have been found that, in similar cases, the number of killed and wounded has varied from ten to twenty; by throwing a common die he decides whether to assign a greater or a less result to the case in view. The rules of the game also explain to him under what circumstances troops have been dispersed by the result of fire, and what would be the probable result of a hand-to-hand fight. Since the time of Von Reisswitz the game has been much modified; and the different forms which it has assumed may be classed in three groups.

The first form lays down a few arbitrary rules based upon general results, and leaves the die to decide in each case when the

troops on one side or the other are compelled to retire, without regard to the losses which they may have suffered. and only taking account of topographical and other circumstances in a most vague and unsatisfactory manner.

The second form is especially adapted to the Minor Kriegsspiel, where but a few troops are employed. and where minute records are kept of the losses of each company and fraction of a company. This produces a perfect representation of a small fight or skirmish, but involves the necessity of employing clerks or assistants, and becomes very tedious when more than two or three companies are engaged.

The third form is employed when an officer of much experience can be found to take the position of umpire; one who from long familiarity with the Minor Kriegsspiel, and from practice in leading troops in action, can form a correct judgment of the possibility or results of any movement, without the necessity of making any calculations or referring to any rules.

The American Kriegsspiel has gradually been developed in the United States service upon the basis of the second form above mentioned. But by the employment of several devices upon the plan itself, it dispenses with the necessity of keeping records, while it offers facilities of instantly determining the results of calculations as minute as those of the Minor Kriegsspiel.

A glance at the maps during the progress of the game shows to the umpire not only the formation and position of the troops, but their present condition and previous history.

Autumn manœuvres are generally recognized in the scheme of military instruction of European armies. The practice in the drill-room and on the parade-ground here find their expression and their application. They are useful in affording to officers, soldiers, and sailors an opportunity to acquire practice in their profession without the great sacrifice of life and property incidental to hostile warfare. They should therefore be made to conform as nearly to the conditions of the latter as to require a similar exercise of the faculties, and to render the forms of warfare to some extent familiar to those who have to apply them.

The most perfect representation of a hostile encounter was once afforded by a distinguished soldier who thought he could save the lives of thousands of his men by occasionally sacrificing a few hun-

dred in the way of instruction. Who would not feel more respect for this spirit than for that of more conservative leaders who have led thousands upon thousands of brave men to be mowed down like sheep because they have vainly assumed that the methods learned by experience and hard practice would suffice to meet the requirments of modern warfare, without taking into consideration the important changes in the armament?

But humanity revolts against these realistic experiments and has suggested methods that approximate as nearly to hostility as is consistent with a proper regard for human life and a measurable economy of resources; and it is by no means to be assumed that these methods are less instructive than the former. If the manœuvres are properly combined with other exercises and investigations, a system of instruction results which is even more useful than that afforded by unnecessary bloodshed, for it fixes the attention firmly upon each point in succession just as a skillful general throws all the strength of his armies upon the several fractions of his enemy and overcomes them in detail, and just as every conscientious and earnest man in other trades and professions devotes all his energies successively to mastering the difficulties of his calling.

To determine how far practice in the Art of War can be taught in time of peace, and without violating what is called in the text-books the "Peace Conditions," let us consider the form of manœuvres that differs the least from hostile encounters.

In general terms, in the autumn manœuvres in Germany a condition of hostility is assumed, the forces available are divided between the opposite sides in accordance with the problem, and the exercise proceeds as if in earnest, with slight modifications to avoid unnecessary destruction of property, until the combatants come within reach of each other's weapons. The umpires then decide the effects and consequences of the firing each in his own sphere, in accordance with recognized rules and principles, based upon the experience of past warfare which has been systematized and digested for the purpose. The defeated troops then fall back as directed by the umpires, and the operations proceed until the problem has been solved, or until the time fixed for the manœuvres has expired.

The following are some of the features in which this exercise differs from war:—

1. The firing is not conducted with ball cartridges.

2. The troops do not fall back from fear of death.

3. They do not collide.

4. The action is sometimes suspended to enable the umpires to decide the result.

5. The farmers' crops are sometimes avoided, where in war they would be trodden down.

6. The ground sometimes shelters troops from sight where they would be exposed in war.

The modifications 4, 5, 6, introduced mainly with a view to economy and like considerations, are far from detracting seriously from the value of manœuvres for military instruction.

On the field of battle the combatants are urged on in the heat of excitement to the attainment of certain ends, and are only too apt to be biased by their immediate surroundings, but in the manœuvres the modifications and pauses serve to fix the attention of officers and men to remoter influences.

It is understood that the manœuvres of the other continental nations are similar in character to those of Germany. The method of deciding the effect of fire under all conditions is identical with that employed in Kriegsspiel, and constant practice in this exercise and applications of its principles, beginning with operations on a small scale on the map and in the field, affords to the umpires excellent preparation for their duties in the manœuvres. In making their decisions account is taken of all the modifying factors dependent upon the nature and circumstances of the troops delivering the fire and those subjected to it.

It is probable in European manœuvres these factors are not computed as in the Minor Kriegsspiel, and in the American practice, but estimated as in the freer form of this exercise. But it should be remembered that by whatever method the Kriegsspiel calculations of the effect of fire are made, they are based upon the results of the experience of war so modified as to take account of improvements in the mechanism and use of weapons, and it must not for a moment be inferred that they depend upon the results of target practice alone.

Thus, military history and statistics form the basis of Kriegsspiel, as the latter forms the basis of the umpire's decisions in the manœuvres of opposing parties.

The highest order of manœuvers cannot be considered independently of Kriegsspiel, nor can the latter attain its highest usefulness unless supplemented by manœuvers; nor can either be developed without a proper study of military history and science.

MEETING 395.

The History and Theory of Cohesive Construction as Applied Especially to the Timbrel Vault.

BY MR. RAPHAEL GUASTAVINO.

The 395th meeting of the SOCIETY OF ARTS was held at the Institute on Tuesday, November 26th, at 8 P.M., Prof. G. Lanza in the chair.

After the reading of the records of the previous meeting, the chairman presented Mr. Raphael Guastavino, of New York, who continued the reading of the paper on "The History and Theory of Cohesive Construction as Applied Especially to the Timbrel Vault," which was begun at a regular meeting of the Society held October 24th.

Mr. GUASTAVINO said: We will begin by investigating the way in which this kind of arch works.

A "timbrel vault" of a single thickness of brick or tile has no more resistance than an arch or vault built by the "gravity system," because, no matter how good the mortar may be, there are only vertical joints, and the bricks or tiles are working as voussoirs, consequently this form of arch belongs to the gravity system, but if we put another course over the first breaking joints, and laid with hydraulic material, we will have the action of the cohesive force in this way, the mortar laid over the first course, or extrados, takes bond with it and also with the course laid on top. As soon as the cement sets, we will have shearing resistance represented by 17,820 lbs. per square

foot (test No. 4873). In this manner we introduce a new additional strength to the arch. But in the gravity system the force of gravity alone is the only force keeping the voussoirs in place by pressure against each other in the joints. These joints are not protected, and any reduction in the width of the joints in consequence of pressure, or weight on the arch, *compromise the setting* of the mortar. For this reason, in the gravity system the mortar serves only as a cushion, also, if cement mortar, because of bad setting, and adds no strength to the arch. In our "cohesive system" with horizontal breaking joints, with 17,820 lbs. per square foot shearing strength, the reduction in the vertical joints is protected so absolutely that, 1st, we can build arches of 20 feet span only 3" thick, using a center of 1" thick, and move it along as soon as a row of tiles is laid, which usually requires about fifty minutes; 2nd, it is common to see the workmen walking over the arch, free from centers of any kind, in some hours after it is built; and 3rd, *we can run the center under the arch again when it is completed, which is the most practical illustration that the arch has had the absolute repose necessary for its settlement.*

These three remarkable circumstances are of great value to architects, as they can be put in the *specifications*, and can be depended upon as absolute proof of the safety of the construction.

But this horizontal breaking joint is not the only great advantage of the system, there are others, the principles of which we will try to explain.

It is evident that if we were able to build an arch without joints it would be the best, having no settlement, but as the gravity system has only voussoirs of stone or brick, a certain number of joints is necessary.

Let us suppose that we have a brick arch of 6 feet span; we shall have of common brick about 26 or 27 joints, these joints being ¼ of an inch thick, represent about 7 inches of mortar, which is compelled to set with all the weight of the voussoirs resting on the centers; the centers contracting, leave the weight or pressure on the mortar, preventing a good setting, and raising the center of pressure of the arch; this happens in all the brick arches, more or less. When this arch raises only 10 per cent of the full span it is very dangerous, because the development of the curve measures very little more than its cord. and the builder or contractor, knowing this, is always afraid when

the centers are removed, and before the architect knows it, *he brings down the center of gravity still further* by hammering in little iron wedges or nails in the joints, covering them with mortar so as not to be seen. This is not good practice, for it destroys what cohesion may still be left in the joints, but has the advantage that it prepares the brick for second-hand material, freeing it from the mortar. In our arch in the same 6 feet we have only 13 joints, ¼ of an inch each, which is only 3¼ inches of mortar; consequently, as we know that the arch with no joints is the best, the one with the least is to be preferred.

There are other advantages equally important. We know that in every arch the curve of pressure changes with the position of the load; this means that every arch must be prepared for work by deflection or tension. Suppose an arch laid in bricks in such a manner as to receive a test for tension, the resistance of this tension depends upon the cohesion of the joints, or the resistance to tension of the mortar. But we said that this cohesion in the brick arches is very unsatisfactory, and is only a cushion in many cases, but when these joints have a good settlement the tension will only equal the cohesive strength of the mortar between the bricks, and with good Portland cement mortar ten days laid this strength is only from 80 to 150 pounds per square inch, when we have for our timbrel arch tensile strength (test No. 4875 and No. 4876) 287 pounds for 10 days, and 159 pounds per square inch for 7 days.

This shows that we have three advantages over the brick arches.

1st. The protection of the vertical joints by introducing the new strength coming from the horizontal breaking joints. These horizontal joints are in the 6′ arch, $1' \times 3$ horizontal joints or $144'' \times 6 \times 3 = 2592''$: in the brick arches 27 joints $\times 4 \times 12 = 1296$ square inches, but the tiles have not only the horizontal, but the vertical, equaling 638; $638 + 2592 = 3230$ for the tile arches, against 1296 for the brick arches. As the cement is the principal element of strength in the construction, if we call it 100 pounds for 10 days' setting, we will have for the brick arches 129,600 pounds, and for the tile arches 323,000 pounds.

2nd. The less number of vertical joints, amounting to only 5 per cent of the full span, while the brick arch has 10 per cent.

3rd. The resistance to the deflection (bending moment).

The result of these advantages is the surprising strength of the timbrel arches, so that no one can at first understand how 15 or 20 feet arches, 3 inches thick, and 10 per cent rise, as we before said, can be laid, then taking away the centers at once, giving them over to the uses of the building in a few hours, when an arch of brick 6 feet span, 4 inches thick, and 10 per cent rise requires for constructing it strong and heavy centers, and repose for several days; and besides that, that 6 feet span, 4 inches thick, and 10 per cent rise is not safe construction; this span requires 8 inches of thickness as all architects and builders know.

We can consider as a safe relation between the brick and timbrel arches an arch 4 feet 6 inches span, 10 per cent rise, 4 inches thick, with cement mortar as is usual in buildings, is equivalent to 12 or 15 feet span, timbrel arch, 3 inches thick, 8 to 10 per cent rise.

All that we have said about the brick arches in comparison with the timbrel arch can be applied to the construction of concrete or conglomerate arches, especially in regard to the inconvenience of using heavy centers, and imperfect settlement of the material. In large arches the cement cannot be put over the arches quickly enough, so that every layer can settle evenly and the excessive use of the pounder kills the cement in such a way that at the moment there seems to be a small settlement; the last layer generally looks right, while inside it is all mud. That is the reason that for forty years these concrete arches have been tried without success, except in small arches, where the helpers that are generally used in this kind of work can control the full span of the arch with one single coat, having a uniform settlement, but not without using more material than necessary.

I give an instance of the use of concrete. In the foundation of the manufactory of Battllo Bros., I specified cement concrete for three feet all along the foundations as a first course, putting on top four courses of brick ($6 \times 12 \times 1\frac{1}{2}$) about the same as we are now using, this was in 1869, twenty years ago,—I gave orders to lay the concrete in layers 6″ at a time; the cement was slow setting, yet I could see some signs of set. The next day when inspecting the work I found it all a mass of mud; it cost me ten days' labor, and many barrels of cement in experimenting with different brands before I ascertained the true cause; it was necessary to adopt an hydraulic

mortar composed of two parts lime, two parts sand, and three parts brick dust, in order to give very slow mortar, because cement requires repose for a certain length of time in which to set, and this putting it on in 6″ courses, and hammering it down, so jarred the whole mass that its rest was disturbed and its setting qualities killed. This can be seen in the use of our tiles; two minutes after the tile is bedded in the arch the cement has begun to set, and cannot be disturbed or used again, when the same cement in the mortar bed will remain several hours without setting.

In May, 1887, I commenced a serious of experiments in the department of Tests and Experiments with the Engineer, A. V. Abbott, and I obtained the following coefficients: —

COMPRESSION TEST.

No. 4817, May 8, 5 days,	. . .	2277 lbs. per square inch.
" 4818, " 3, 5 "	. . .	1624 " " " "
" 4869, June 6, 5 "	. . .	1430 " " " "
" 4870, " 6, 5 "	. . .	2911 " " " "

An average of 2060 lbs. per square inch.

No. 7473, Oct. 21, 1889, 1 year, .	.	3290 lbs. per square inch.

TRANSVERSE.

No. 4871, June 6,	. . . . .	90 lbs. per square inch.

TENSION.

No. 4875, June 7,	. . . . .	287 lbs. per square inch.

SHEARING STRESS.

No. 4873, June 6, in Portland Cement,	124 lbs. per square inch.
" 4872, " 6, in Plaster of Paris,	84 " " " "

The formula I am using is $TC = \frac{LS}{4r}$ for concentrated load, and $TC = \frac{LS}{8r}$ for distributed load, where T = thickness of arch in middle, or area of cross section. C = Coefficient = 2060 lbs. per square inch breaking load. S = Span. r = Rise of arch.

We use the first formula to get the thickness necessary at the center of the arch with a single load and independent of the weight of the arch itself. After that we find the line of the extrados of the arch in a graphical manner, derived from the formula given by Dejardin, for tracing the equilibrium profile of the extrados for the vaults, giving the section of the arch in the skewbacks or base of the arch on each side.

MEETING 396.

The Development of Magazine Guns for Army Use.

BY CAPT. A. H. RUSSELL, U.S.A.

The 396th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, Dec. 12th, at 8 P.M., President Walker in the chair.

After the reading of the records of the previous meeting, the President introduced Capt. A. H. Russell, of the Ordnance Department U. S. Army, who read a paper on "The Development of Magazine Guns for Army Use."

Capt. RUSSELL said: The first magazine gun used extensively in war was the Spencer. This has a tubular magazine in the butt stock. The cartridges lie end to end, being forced forward by means of a spring, and fed over the swinging breech-block directly into the firing chamber by working a lever underneath. It was used by some of the Northern troops during the Rebellion.

The Henry, afterwards known as the Winchester, was invented before, but it did not come into prominence until later, though the Henry was used to some extent by Northern troops during the Rebellion. This has a tubular magazine under the barrel. It is a bolt-gun, the breech-bolt being opened by a lever underneath.

The earlier magazine bolt-guns required some sort of a carrier to transfer the cartridge from the magazine to the firing chamber. This first system had a sliding carrier, and as the lever was worked the carrier was raised vertically.

The Spencer, Henry, and Winchester are all American inventions. The Winchester was tried in Switzerland, and then the Vetterli gun was modeled on it, as far as the magazine mechanism goes. The carrier of the Vetterli moves vertically, but it is worked by a bolt moving forward and back, instead of by a lever underneath, as in the Winchester. The action of the bolt is like a door bolt.

We now come to another American invention,— the Ward Burton gun,— where the carrier is a rocking piece or spoon, so arranged

that the cartridge, being forced on the spoon from the tubular magazine under the barrel, would be tilted up as the bolt is drawn back, so that the forward movement of the bolt would drive it into the chamber.

The new French gun (Figs. 1 and 2), and the similar gun on trial in Germany (Figs. 3 and 4) are examples of this action.

Fig. 1.

Fig. 2.

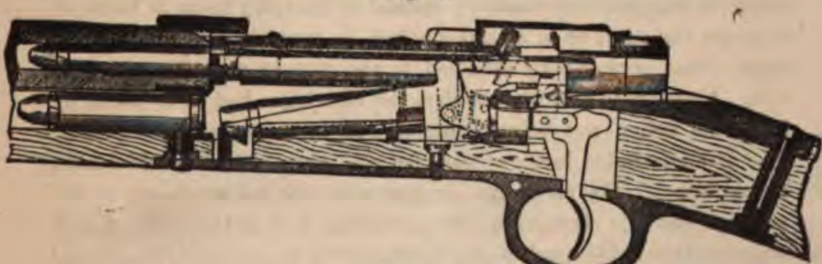


Fig. 3.

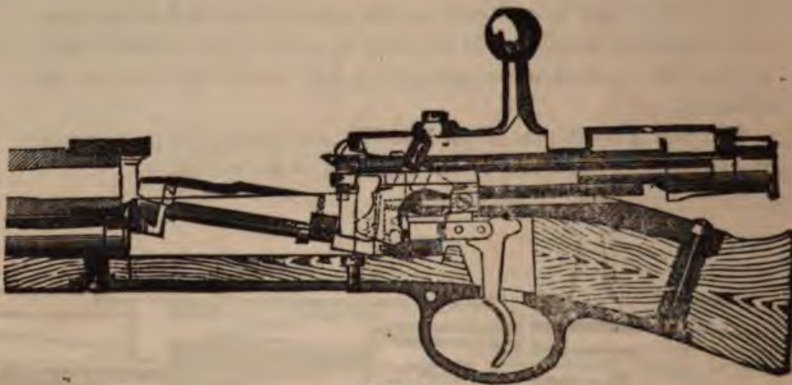


Fig. 4.

The Hotchkiss bolt-gun simplified matters very much because it dispensed entirely with the carrier. In this the magazine leads under the bolt right into the chamber from the butt stock, so that one cartridge after another is presented in front of the bolt and pushed into the chamber.

In the Evans gun there is a revolving piece running through the butt stock, with four grooves which are filled with cartridges; and, as this piece revolves, the cartridges are pushed forward by a spiral ledge, so that they work along, one after another, and come into the chamber. This is worked by a lever below.

The Hotchkiss and Evans guns are American.

Certain devices called "quick loaders" now claim attention, as they were made in order to take the place of magazines, when people thought (and some think so now) that it was just as well to get along with a single-loading gun, having the cartridges placed where they could be reached very readily; instead of carrying them in belts, or over the shoulder, or in a cartridge box, to have them in some receptacle, either permanently attached to the gun, or made to attach at will. From these cartridge holders the cartridges had to be taken by hand, the action not being automatic, as in magazine guns proper. The first detachable device of this kind was invented by Capt. Metcalfe, of our army. The cartridges are packed in the holder or case at the armory, and it is clamped to the gun when it is to be used. Fig. 5 shows a detachable quick loader, invented by General Kelton, of our

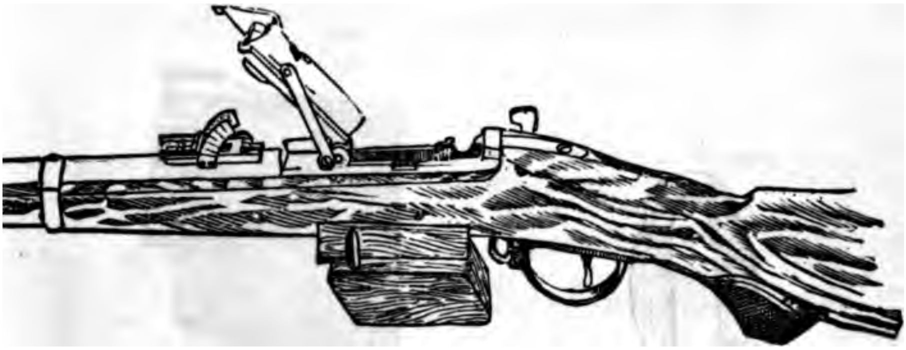


Fig. 5.

army. It is shown attached under the stock. Like the Metcalfe, it is a wooden block, perforated to hold the cartridges, but it has to be filled by the soldier.

Now we come to a very important development in magazines. These differ from the others I have described in this way, that the cartridges lie side by side, instead of being placed end to end, as in the tubular magazines.

The Lee gun is an example of this. An opening is made in the bottom of the receiver down through the stock, and the magazine is inserted from below. When one magazine is exhausted, it is taken out, and another one is put in its place. Several of these magazines are carried by the soldier, and belts are made to hold the prepared magazines. The magazines are made of steel. They have to be strong enough not to get dented or knocked out of shape, and each one has to be provided with a spring.

Figs. 6 to 8 illustrate this system. Fig. 6 gives a longitudinal section, showing the magazine in place; Fig. 7 a cross section, with the magazine removed. Fig. 8 gives a side view of the most recent form of Lee magazine.

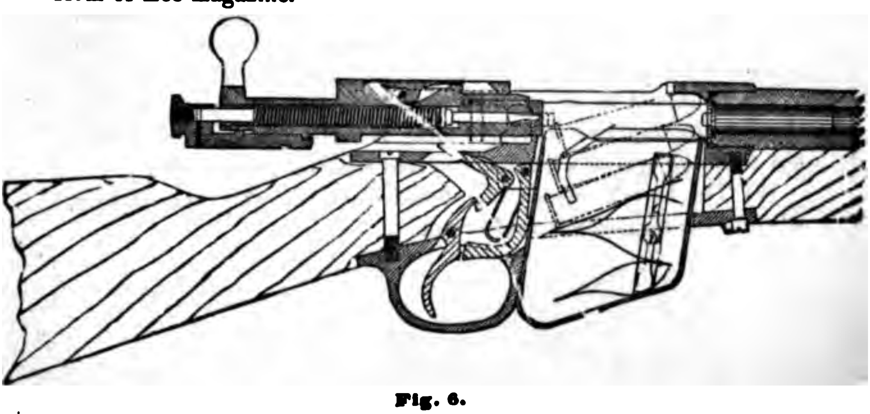


Fig. 6.

Fig. 7.

Fig. 8.

The English were not quite satisfied with a magazine that could be taken off, nor even with one that could not, so they chained one magazine to the gun, but had other detachable ones, as already described.

The Burton magazine is a detachable hopper, similar to the Franklin feed case for the Gatling gun, and made to feed cartridges by gravity down to a sliding carrier, which conveys them one by one to the receiver.

According to an article of October 16, 1887, in the *Revue du Cercle Militaire*, a perfect magazine gun should fulfill the following requirements: —

(1) The magazine should be permanently fixed to the piece.

(2) It should carry only as many cartridges as the soldier can fire rapidly in succession, without fatigue, and without seriously checking the forward impetus so important to a successful attack.

(3) It should afford control of the expenditure of ammunition by allowing occasional pauses, during which the lines may be re-formed.

(4) The form should be such that the cartridges can be inserted all at once in filling the magazine, and readily removed when necessary.

(5) It should be so constructed that cartridges can be inserted through the magazine for single firing as well as for rapid firing, without requiring special adjustment to pass from one to the other.

(6) The breech mechanism should work smoothly and rapidly, whether the magazine is used or not.

(7) The magazine should show at all times just how many cartridges remain in it for use.

(8) In an assault, even after the magazine has been emptied by a rapid preliminary fire, it should be possible to refill the magazine during the rush if necessary, so that on reaching close quarters with the enemy the soldier may be able to deliver a rapid and abundant fire after the bayonet charge.

(9) The arrangement of cartridges should be such that the bullets of the cartridges cannot be upset and injured in the magazine.

(10) There should be no danger of the explosion of cartridges in the magazine.

(11) It should allow the main parts to be dismounted, cleaned, and put together again, even in the field or under fire if necessary.*

(12) The gun should be strong and simple, even if rude in construction, to stand the wear and tear of drill and service.

(13) It should not require removal from the shoulder in continuous firing.

The *Revue Militarie de l'Etranger* adds: —

(14) In continuous firing, the gun should not require removal from the shoulder, nor removal of finger from the trigger.

(15) Filling the magazine should not require opening the breech, nor withdrawing the charge if the piece is loaded.

(16) It should be as easy to refill the magazine as to put a single cartridge into the simple breech loader, cartridges being carried in light boxes to serve as chargers.

The 4th, 5th, 15th, and 16th requirements indicate that the magazine should allow refilling by inserting the cartridges one at a time, when partly exhausted, or all at once when the magazine is empty.

Other authorities say the magazine should be detachable, easily replaced when empty by another full magazine held in reserve, but all agree that the perfect magazine should allow a fresh supply of cartridges to be rapidly added to the gun for instant use. The great principle sought for, first in breech-loaders, now in magazine guns, has been "to reduce to a minimum the time during which the soldier remains with gun unloaded after each shot. It is not always necessary for a man to fire rapidly, but he should be able to load rapidly, as this gives him more confidence and affords a longer time for aiming with care.

* This seems to be a very unnecessary demand.

I claim for Major W. R. Livermore, U. S. Army, and myself that we were the first to enunciate many of these very principles. Also, that we were the first to present for trial a magazine depending upon these principles, and not requiring an essential part of the working mechanism to be detachable. We had the magazine fixed, and depended on light packing cases for rapidly refilling it. Our first attempt was in the transformation of the Hotchkiss gun, as shown in Fig. 9. A slot in the butt-stock opens into the tubular magazine, and this slot can be filled by hand with loose cartridges, or by means of the prepared packages. The cartridges are then fed forward through the tube.

Fig. 9.

We then devised a fixed magazine which fulfilled most of the conditions just spoken of. This magazine is placed at the side of the receiver, with an opening at the top where the cartridges can be inserted. This is arranged so that one cartridge can be put in at a time, or all can be put in at once from a packing case which is placed over the mouth of the magazine, the cartridges being forced down into the magazine with the finger, and the case thrown away. This can be done whether the gun is loaded or not. Means are also provided for cutting off the magazine if desired. There is also a slot in the side of the magazine which enables us to see how many cartridges remain ready for use.

Fig. 10 is cross section of this gun through the magazine, and Fig. 11 represents the packing case used for filling this magazine and the Hotchkiss modification above described. Fig. 12 is a view of the gun and magazine. The bolt was made to work forward and back without turning, a principle followed in the more recent Mannlicher gun mentioned below.

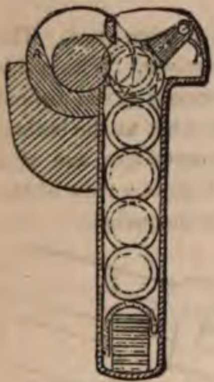


Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

A recent Swiss gun—the Rubin—is filled from packages idendical with those devised by us. Fig. 13 is an illustration of the Rubin packing case, which is also used with the Schulhoff gun described below. In the Rubin gun the breech bolt has to be drawn out before filling the magazine, which is only accessible through the receiver, being in position like that of the Lee, but fixed instead of detachable.

The Schulhoff gun is another of the recent foreign guns. The magazine is drum-shaped, and placed under the receiver. Within this drum is a revolving carrier, which causes the cartridges to run around a central spindle, and presents them one after the other at the bottom of the bolt. This magazine, can be filled with cartridges one at a time or all at once from a packing case. Fig. 14 gives a view of the Schulhoff gun; Fig. 15 a cross section through the magazine.

Fig. 14.

Fig. 15.

In the Austrian gun, the Mannlicher, the bolt, instead of being pushed in and turned, is operated by a forward-and-back motion simply. The magazine is fixed under the receiver, like the Rubin. A packing case filled with cartridges is inserted in the magazine and left there, the cartridges being fired from the case, and when the case is emptied it drops through a slot in the bottom of the magazine. This gun cannot be used for single firing, and the cartridges cannot be inserted one at a time. It also has the disadvantage that it is necessary to open the breech to fill the magazine, as the packing case has to be inserted through the receiver.

Fig. 16 shows the Mannlicher gun, and Fig. 17 the packing case used to fill it. Fig. 18 shows the small caliber cartridge with projecting flange used in the Mannlicher. The flanges have to be overlapped in the magazine to leave the top one free to move forward with the bolt, and a corresponding arrangement is necessary in the packing case, giving it a definite top and bottom.

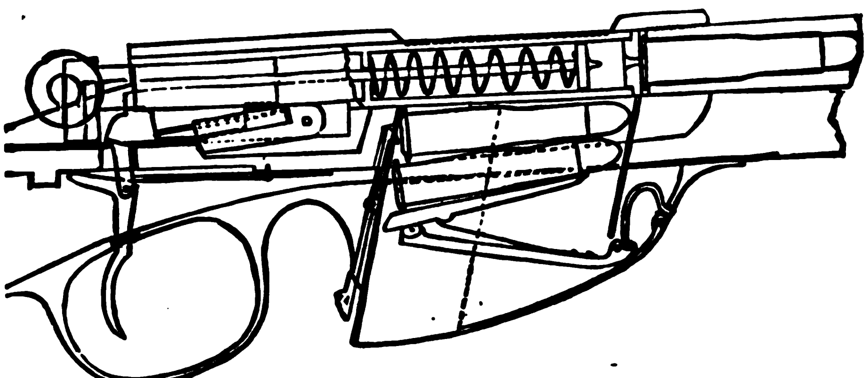


Fig. 16.

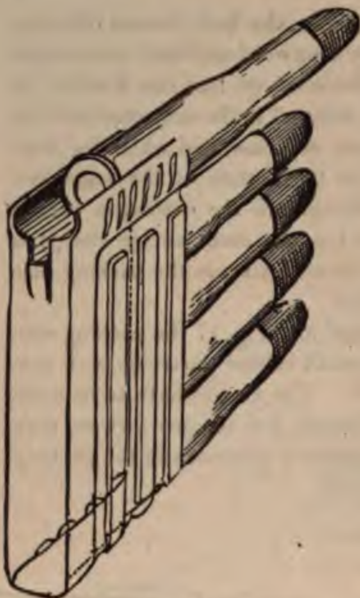


Fig. 17.

Fig. 18.

Fig. 19.

Fig. 20.

In place of the German gun, illustrated above in Figs. 3 and 4, one having a magazine similar to the Mannlicher has been adopted for the German army, the bolt being of the old pattern shown in these figures. The use of flangeless cartridges allows the insertion of the packing case either side up. A groove around the base of the new cartridge gives a hold for the extractor, as shown in Fig. 19, but this does not show the bottle shape of the German cartridge.

Fig. 20 shows the U. S. service cartridge caliber .45. The cartridges are shown in actual size.

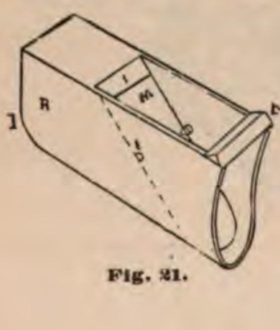


Fig. 21.

Capt. Russell also exhibited an inspecting mirror of his invention for examining the bore of breech-loading small arms. Fig. 21 gives a view of this instrument, and Fig. 22 illustrates its use with the Springfield rifle.

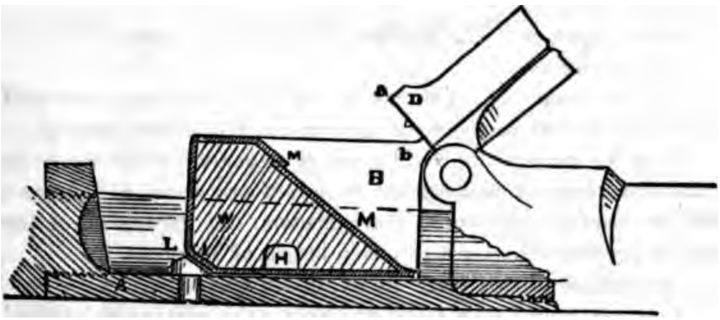


Fig. 22.

Most of the guns already spoken of were exhibited, as were also the Peabody, the Colt rifle, and several others.

Numerous drawings, representing sections, etc., of many styles of guns, arranged in the order of development, were used to illustrate the lecture. Among them were drawings of the Maxim automatic recoil rifle, and an electric gun. Illustrations were given of magazine guns, like the Spencer shot gun, and the Colt rifle, operated by means of a slide under the barrel; also of the Burgess gun, operated by means of a slide on the small of the stock. The latter has the advantage of operation with the right hand, while the left hand, grasping the barrel, steadies the piece.

At the close of the paper, Capt. Russell expressed his thanks for the courtesy shown by Hartley & Graham, of New York, William Read & Son, and J. P. Lovell Arms Co., of Boston, in offering and furnishing arms for exhibition.

MEETING 397.

The Physical Properties of Iron and Steel at Higher Temperatures.

BY MR. JAMES E. HOWARD.

The 397th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 9, 1890, at 8 P. M., Prof. Gaetano Lanza in the chair.

After the reading of the records of the previous meeting, the Chairman introduced Mr. James E. Howard, of Watertown Arsenal,

who read a paper on "The Physical Properties of Iron and Steel at Higher Temperatures."

Mr. HOWARD said: The results which I have the pleasure of presenting are from experiments made at the Watertown Arsenal.

First referring to the coefficients of expansion or dilatation by heat. The range of temperature employed was about 210 degrees Fahr., as shown by mercurial thermometers, the expansion of the metal being observed over a specimen length of 35 inches.

The method of measuring the expansion was as follows: —

A gauged length was laid off on the experimental bar and defined by drilled and countersunk holes. A micrometer, mounted on a carrying frame which had conical points made to enter these drilled holes in the specimen, enabled the length of the latter to be measured and compared with the length of a standard bar. When in use the standard bar was kept at a uniform temperature in a bath of ice-water.

The experimental bars were first placed in the ice-water bath and initial measurements of their lengths taken, after which they were transferred to a bath of hot oil and again measured. Generally, the specimens were returned to the cold bath and remeasured for the purpose of verifying the observations previously made. The bars remained in each bath at least two hours before measuring. The micrometer was compared with the standard before and after each reading on the experimental bar.

Tables I and II state the chemical composition and the coefficients of expansion determined with two series of steel and iron bars.

Table I. FIRST SERIES OF BARS.

Metal.	Marks.	Chemical Composition.				Coefficient of Expansion. Per degree Fahr. per unit of length.
		C.	Mn.	Si.	Fe. by difference.	
Wrought Iron..	S. 3.	..	..	..	....	.0000067302
Steel	1-833	.09	.11	..	99.80	.0000067561
"	2-123	.20	.45	..	99.35	.0000066259
"	3-782	.31	.57	..	99.12	.0000065149
"	4-795	.47	.70	..	98.93	.0000066597
"	5-803	.51	.58	.02	98.89	.0000066202
"	6-797	.57	.93	.07	98.43	.0000063891
"	7-823	.71	.58	.08	98.63	.0000064716
"	8-750	.81	.56	.17	98.46	.0000062167
"	9-756	.89	.57	.19	98.35	.0000062335
"	10-334	.97	.80	.28	97.95	.0000061700
Cast (Gun) Iron	......	..	..	..	.....	.0000059261
Drawn Copper.	......	..	..	..	.....	.0000091286

Table II. SECOND SERIES OF STEEL BARS.

Marks.	Chemical Composition.							Coefficient of Expansion. Per degree Fahr. per unit of length.
	C.	Mn.	Si.	S.	P.	Cu.	Fe. by difference.	
1	.17	1.13	.023	.122	.079	.040	98.436	.0000067886
2	.20	.69	.037	.130	.078	.260	98.605	.0000068567
3	.21	1.26	.080	.140	.059	....	98.251	.0000067623
4	.25	1.07	.110	.096	.080	.047	98.337	.0000067476
6	.26	1.26	.070	.112	.060	.038	98.200	.0000067102
7	.26	1.28	.070	.115	.062	.035	98.178	.0000067175
8	.28	1.23	.090	.168	.090	.178	97.964	.0000067794
9	.43	.97	.050	.080	.096	.024	98.350	.0000066124
10	.43	1.08	.037	.080	.114	.233	98.026	.0000066377
11	.53	.75	.100	.078	.087	.174	98.281	.0000064181
12	.55	1.02	.050	.078	.120	.150	98.032	.0000066122
14	.72	.70	.180	.070	.130	.230	97.970	.0000064330
15	.72	.76	.200	.056	.086	.186	97.982	.0000063080
16	.79	.86	.210	.084	.093	.096	97.867	.0000063562
17	1.07	.07	.130	.010	.078	.060	98.696	.0000061528
18	1.08	.12	.190	.011	.020	Tr.	98.579	.0000061702
19	1.12	.10	.090	.013	.018	Tr.	98.659	.0000062589
20	1.14	.10	.150	Tr.	.018	Tr.	98.592	.0000060716
21	1.17	.10	.100	Tr.	.018	....	98.612	.0000061332
22	1.31	.13	.190	.011	.026	Tr.	98.333	.0000061478

From these tables it appears that the expansion of wrought iron and mild steel is greater than that of hard steel and cast iron. The expansion of mild steel was found to be about 67 ten millionths of its length per degree Fahr. In steel of 1 per cent carbon the rate of expansion falls to 61 ten millionths, and the expansion of the cast iron was less than that of the hard steel.

In the first series of experiments variations in the rate of expansion followed approximately the carbon of the steels, and also the quantity of iron present.

In the second series there was a wider range taken by the other elements, and indications here led to the conclusion that carbon has the greater influence upon the rate of expansion. This deduction applies to annealed metal, or that which has been finished hot.

Ten bars of the first series, representing steels containing from .09 to .97 per cent carbon, were subjected to the special treatment of being heated a bright cherry red and quenched in oil, reheated and quenched in water. The first quenching was done in oil at 80 degrees Fahr.

The behavior of the bars under rising temperature seemed erratic, especially the high carbon bars which appeared to have an abnormally low rate of expansion. Returning the bars to the cold bath their contraction, although not identical, agreed fairly well with their expansion observed previous to the oil treatment.

The seemingly erratic behavior under rising temperature was now explained by the permanent changes in lengths which were found to have occurred while heating and cooling to and from 235 degrees Fahr. Generally the bars were found permanently shortened at the close of these observations, a feature very pronounced in the bars containing the highest amounts of carbon.

Following the oil treatment the same bars were again heated bright cherry-red and quenched in water at 50 to 55 degrees. The same kind of behavior observed after the oil treatment was now exhibited, but in a more marked degree. Estimating the coefficients from the expansion during rising temperature, but the values of which are vitiated by the permanent changes in length then going on, and a bar containing .97 per cent carbon had an apparent coefficient of only 23 ten millionths of its length, whereas the contraction during falling temperature indicated a coefficient of 73 ten millionths, and three other bars of the series gave results above 70 ten millionths, under falling temperature.

Heretofore the bars had displayed lower coefficients as the amount of carbon they contained increased, but now after hardening in water there resulted a decided elevation of the coefficients in the high carbon steels.

For a period of six hours the quenched-in-water bars were kept at a temperature of 300 degrees. This caused a further permanent diminution in length when cooled, most conspicuous in the high carbon steels, yet their coefficients remained highest. Finally, the bars were annealed by heating cherry-red and cooling in pine shavings, which restored the rates of expansion nearly to the primitive values.

If we may judge from the diminution in lengths, the mild steels more nearly reached a state of repose than the hard steels under the moderate temperatures which preceded final annealing. Additional experiments are needed to establish the minimum temperature at which the restoration in the rate of expansion is complete and the length of time necessary to maintain that temperature.

The moduli of elasticity were obtained with the first series of bars at atmospheric temperatures, and again at higher temperatures up to 495 degrees Fahr. The specimens were strained in a bath of hot oil. Micrometer observations were taken in a similar manner to those when determining the coefficients of expansion, that is, the conical points of the measuring instrument reached down through the surface of the oil in the bath to the drilled holes in the specimen, and enabled the strains to be measured. Elevation of temperature is found to lower the modulus of elasticity. The different grades of steel, wrought iron, and cast iron behaved alike in this respect, although differing in degree.

The reduction in the modulus of elasticity for a range of about 400 degrees, beginning with atmospheric temperature, was found from 3,595 to 8,294 lbs. per square inch per degree Fahr. for the steels. Lower values were obtained with the cast iron and intermediate values with the wrought iron.

It does not appear, however, that the reduction takes place at a uniform rate with increase of temperature; or, stated differently, the reduction is not directly proportional to the expansion of the metal by heat.

Two bars of the second series were experimented with at temperatures reaching 1,400 degrees Fahr. The heating was done in a hot-air muffle, estimating the temperatures of the tests from the expansion of the metal between reference points 10 inches apart. A specimen which contained .26 per cent carbon had an apparent modulus of elasticity of 29.000,000 lbs. per square inch at 70 degrees Fahr., which was lowered to 16,981,000 at 1,353 degrees. And another specimen containing 1.07 per cent carbon showed a reduction from 29,771,000 at 70 degrees, to 14,173,000 lbs. per square inch at 1,400 degrees Fahr.

Observations on these two bars at intermediate temperatures indicated an accelerating rate of reduction of the modulus of elasticity as the temperature increases. Overstraining at atmospheric temperature causes a temporary reduction in the modulus of elasticity. The effect of overstraining at high temperatures upon this point is not conclusively indicated by these experiments, the evidence of different tests being of a conflicting nature. This important feature will be investigated in subsequent tests.

The experimental bars under tensile test were enclosed in a hot-air muffle. The heating was done by means of gas burners arranged within the muffle and below the specimen. By varying the number of burners in use, the pressure of the gas, and changing diaphragms in the muffle, a fairly uniform temperature was maintained at any desired point. The expansion of the heated specimen was measured in the same manner as described for the coefficient of expansion determinations. The holes defining the gauged lengths of the tensile specimens were six inches apart. It is not thought that the error in measuring the expansion exceeded .0002", which corresponds to a variation in temperature of 5.4 degrees, according to the lowest coefficient of expansion used. It was assumed that the rate of expansion continued uniform, and the coefficients developed at moderate temperatures were used in estimating the higher temperatures of the tests. The reports containing the full details of the tests state the observed expansions.

The elastic limit appears to diminish with increase of temperature. The limit here referred to is that at which the rate of elongation shows a rapid increase under equal increments of load. With some metals at certain temperatures the elastic limits thus defined correspond closely with the limits at which permanent sets are discovered. In other cases the elastic limit is vague and uncertain.

According to the definition adopted, it is probable that the elastic limits as recorded are not too low, and the exclusion of permanent sets would in most cases give lower values. Steel of .09 per cent carbon, which had an elastic limit of 33,000 lbs. per square inch, at 70 degrees had an elastic limit of 16,000 lbs. per square inch at 934 degrees temperature.

The tensile strength does not appear to follow the same law which governs the elastic limit. Its value diminishes for a time, then increases, and afterward diminishes. Beginning with zero temperature, the tensile strength diminishes with increase of temperature, until a minimum is reached between 200 and 300 degrees. From this temperature of first minimum strength the metal displays increased tenacity as the temperature rises until a maximum is reached at 400 to 650 degrees Fahr. From the temperature of maximum strength the tenacity diminishes until the highest temperatures are reached covered by these experiments. The mild steels appear to

reach the place of first minimum strength somewhat earlier than the hard steels. The hard steels from this first minimum increase in strength rapidly until the highest strength is attained, after which a rapid decline follows. The mild steels retain a high strength over a wider range of temperature, and do not lose in strength so rapidly as the harder metal. The greatest loss observed in passing from 70 degrees to the place of first minimum strength was 6.5 per cent at 295 degrees, which was shown by a bar containing .89 per cent carbon. The greatest gain in per cent over the strength at 70 degrees was 25.8 per cent, shown by steel of .09 per cent carbon, although in pounds per square inch it was exceeded by steel of .57 per cent carbon where the gain was 15,120 lbs. per square inch, or 12.8 per cent. The total difference in the strength of steel containing .57 per cent carbon between 214 and 587 degrees maximum and minimum places respectively was 21,200 lbs. per square inch. As higher temperatures are reached the several grades of steel approach each other in strength. Thus steels which differ in tensile strength over 100,000 lbs. per square inch at atmospheric temperature differ at the temperature of 1,600 degrees less than 10,000 lbs. per square inch. Their relative positions are retained throughout, that is, steels which are strongest cold are also strongest hot, at least up to the highest temperatures reached by these experiments.

Referring to the relative influence of higher temperatures upon the elastic limit and tensile strength, steel of .09 per cent carbon at the temperature of 460 degrees reached the maximum observed tensile strength for this grade of metal, and displayed a strength of 125.8 per cent that at 70 degrees, but at this time the elastic limit was 78.2 per cent that of the cold bar, and at 847 degrees the tensile strength was 8.4 per cent above the cold metal, while the elastic limit was only 51.5 per cent that of the cold bar. The other grades of steel behaved in a similar manner with less pronounced differences in the harder metal. One grade of wrought iron, designated by the letter B, resembled the mild steel in its behavior. Another wrought iron, called iron A, furnished an exception to the rule, that the elastic limit steadily diminishes with increase of temperature. At 689 degrees this iron had an apparent elastic limit 102.2 per cent of that found at 70 degrees. Iron A had been strained with 42,320 lbs. per square inch seven years before these hot tests were made, and this particular

iron was selected because it had been found excessively red-short at a welding temperature. The metal showed high strength, and not until reaching 1,568 degrees temperature did its hot-short crumbling nature appear. The cast iron gradually increased in strength up to 900 degrees, above which temperature the strength slowly diminished. At 1,600 to 1,700 degrees the surfaces of the specimens after rupture were broken by numerous fine cracks. It is remarkable that the cast iron at these high temperatures had about the same strength as the steels which were so much stronger cold.

Total elongation is generally greatest at ordinary temperatures. Although the metal is capable of being worked under the hammer at high temperatures, it does not then appear to have sufficient strength within itself to develop large elongation. Local contraction at the place of rupture is distributed over so large a part of the specimen at the highest temperatures that elongation independent of local contraction is not at all times clearly shown. Furthermore, as the stress per square inch on the contracted section increases as the metal draws down, it is difficult to distinguish when general elongation ceases and when the stretch is confined to the section about to rupture, unless the specimen is accessible for inspection.

The elongation of the metal under stresses below the tensile strength presents interesting features. Thus, certain bars show a yielding point at or slightly above the elastic limit, at which time stretching will continue without increase of stress, or even under reduced loads. At atmospheric temperature this yielding rarely occurs but once, and is followed by a gradual elongation having an accelerating tendency as higher loads are reached. There may follow a period of abnormal rigidity immediately after this yielding point, but of short duration. Under moderate temperatures — 200 to 400 degrees — several such yielding points have been observed, or alternate periods of relaxation and rigidity under increasing stresses.

This behavior gives a zig-zag appearance to the curve representing the tensile test.

Observations on the contractile force developed during cooling showed the same kind of behavior took place under falling temperature. It will be observed that these phenomena take place at a time when the metal is gaining in strength under rising temperature. Further, this peculiarity is noticed: that greater rigidity exists under

certain stresses at intermediate temperatures than at either higher or lower temperatures. An illustration of this kind is furnished by a bar of .31 per cent carbon tested at 569 degrees, which displayed less elongation under stresses above 50,000 lbs. per square inch, than other bars of the same grade of metal tested at higher or lower temperatures.

The stress on the ruptured section resembles somewhat but not closely the curve of tensile strength. The speed of testing affects this value more or less, and failure in detail may render it difficult to distinguish when local contraction ceases and rupture begins. With hard and brittle metal the stress on the ruptured section does not differ largely from the tensile strength: the converse is true of ductile metal. Steel of .09 per cent carbon tested at 492 degrees reached 118,100 lbs. per square inch stress on the contracted section at the time of rupture. The tensile strength referred to the primitive area was 64,560 lbs. per square inch. The contraction of area at the place of rupture also varies with the temperature of the metal. It appears that contraction of mild and medium hard steel is somewhat less at 400 to 600 degrees than at atmospheric temperature, and within this range of temperature there is a tendency to fracture in an oblique direction across the bar. This characteristic is significant in so far as it harmonizes with the brittleness observed in bending tests at these temperatures. The hard steels showed substantially the same contraction up to 500 degrees. Above 500 or 600 degrees the contraction increased with the temperature, with the exception of the hardest grades, which showed a stage of diminished contraction at 1,100 to 1,200 degrees, until at the highest temperatures some of the bars were drawn down almost to points. A specimen of .37 per cent carbon, fractured at 1,572 degrees, contracted 98.9 per cent. Occasionally there are indications specially noticeable when large contraction occurs that rupture in some specimens begins at the center of the bar. A test was discontinued after reaching 94.4 per cent contraction of area, the temperature at the time was 1,451 degrees. By filing away a portion of the outside metal after cooling, a cavity at the center of the bar was disclosed. Center-punch marks on the surface of the specimen near the place of rupture have elongated upwards of 300 per cent.

The rate of speed of testing may, within limits, modify the results with ductile metal at atmospheric temperature, and has a decided

influence upon the apparent tenacity at high temperatures. The ordinary rate of speed in making these tests was from five to ten minutes each, according to the temperature and the amount of ductility displayed. A series of tests was made with steel containing .81 per cent carbon at ordinary rates of speed, and also rapid tests. The time required to reach the maximum stress in the latter class was from two to eight seconds of time. This metal which, at ordinary temperature, has little ductility displayed about the same strength, whether rapidly or slowly ruptured, from the temperature of the testing room up to about 600 degrees. Above this temperature the apparent strength of the rapidly-fractured specimens largely exceeded the others. At 1,410 degrees the slowly-fractured bar showed 33,240 lbs. per square inch tensile strength. At the same temperature a bar tested in two seconds showed 63,000 lbs. per square inch tensile strength, as nearly as could be weighed. This illustration is an extreme one of its kind. On the other hand, prolonged stress appears capable of rupturing the metal under loads below those which were required at the adopted speeds of these tests, but the differences are not so marked as those due to rapid testing.

Such considerations naturally lead to the inquiry: What is the maximum tensile stress a metal can indefinitely sustain at different temperatures, and at what temperature does the value of such stress become reduced to zero.

A number of bars were strained hot and subsequently ruptured cold. The effect of such treatment appears to depend upon the magnitude of the straining force and the temperature in the first instance. There is a zone of temperature in which the effect of hot straining elevates the elastic limit above the applied stress, and above the primitive value, and if the straining force approaches the tensile strength, there is also a material elevation of that value when ruptured cold. These effects have been observed within the limits of 335 and 740 degrees. Bars of .57 per cent and .97 per cent carbon, respectively, overstrained within the zone of 400 to 1,000 degrees, displayed less contraction, including that which occurred during the hot test and when finally ruptured cold, than the original cold tests displayed, which behavior is in accord with the brittleness observed in some metals under bending tests after similar treatment. After exposure to higher temperatures, there occurs a gradual loss in both elastic

limit and tensile strength, and generally a noticeable increase in the contraction of area. But simply heating without straining was found to anneal and lower the strength of bars of .97 per cent carbon exposed to temperatures of 1,529 and 1,684 degrees respectively, the contraction of area, however, remaining unchanged.

The data thus far developed seem insufficient to explain the relative influence on the final strength of the metal due to exposure to high temperatures, the duration of such exposure, and the tensile stress then applied.

It does not seem inconsistent with observed facts to believe that each of these features may arrive at a stage of relative greatest importance at different places along the thermometric scale.

The color of the bars after cooling was not sensibly changed by temperatures below 200 degrees. After 300 degrees the metal was light straw colored; after 400 degrees, deep straw; from 500 to 600 degrees, purple, bronze colored, or blue; after 700 degrees, dark blue and blue-black. After 800 degrees the final color affords less satisfactory means of approximately judging of the temperature, the color remaining a blue-black and darker, until a thick magnetic oxide is formed. A smooth glazed surface was found on specimens heated to 1,000 to 1,200 degrees, which offered considerable resistance to the effect of acids, and against corrosion in a damp atmosphere. The oxide tints found at lower temperatures were immediately removed by the action of acids. At about 1,100 degrees the surface oxide reaches a tangible thickness, a heavy scale of .001 of an inch to .002 of an inch forming as higher temperatures are reached. The red oxide appears at about 1,500 degrees Fahr. When the oxide has a tangible thickness, it is more or less loosened from the surface of a ductile metal ruptured cold. Some specimens ruptured after exposure to the lower temperatures of 600 to 700 degrees have had the surface coloring slightly broken, but such is not generally the case. The fractures of specimens with straw-colored cylindrical surfaces were not colored. Those with blue surfaces showed fractured ends deep straw and brown. The fractures of dark blue and blue-black specimens agreed with the cylindrical surfaces. The specimens were allowed to cool immediately after rupture, hence the surfaces of the fractured ends were exposed to the atmosphere only a brief period of time, while at the maximum temperature.

Specific gravity determinations, although the results lack uniformity, show differences thought to be sufficiently pronounced to indicate that in general the density of the metal is materially diminished in the vicinity of the place of rupture of tensile specimens, and that this diminution takes place in the different grades of steel, in bars ruptured under different conditions of temperature, stress, and contraction of area.

The specific gravity of the truncated ogival ends of fractured tensile specimens has been found .2 per cent lighter than samples from the original hot-rolled bars. Strain caused by the application of a stress inferior to the elastic limit appears to take place at once. No difference in the deflection of a transversely loaded shaft was detected at the highest speed experimented with when the stresses changed from tension to compression in one forty-fifth of a second, the shaft being run at atmospheric temperature, and, when under the highest load, with a maximum fiber stress of 50,000 lbs. per square inch. Common experience has shown that the full effect of a load superior to the elastic limit is not immediately felt in the elongation of a ductile metal, which appears to be true also at higher temperatures. It is difficult to make a direct comparison of the rate of flow at different temperatures, as the elastic limit and tensile strength are changing in the meantime. A number of examples point to the conclusion that a more sluggish slower rate of flow may take place at high than at low temperatures. A specimen of steel of .97 per cent carbon was observed for a period of three hours, during which the elongation continued at nearly a uniform rate of speed, stretching about .0008 of its length each five minutes, under a stress of 20,000 lbs. per square inch. The initial and final temperatures of the test were 1,170 and 1,189 degrees respectively. Another example furnished by the same grade of metal, in which the observations were limited to one hour, showed the mean rate of flow to be .0015 per unit of length per five minutes, with a slightly accelerating tendency. The stress was 5,000 lbs. per square inch, and the initial and final temperatures 1,505 and 1,494 degrees respectively.

Heretofore we have been considering the effect of higher temperatures upon the strength of the metal exposed to simple tensile stresses.

Experiments were made with riveted joints, in steel boiler plates,

at temperatures from 70 to 700 degrees, over which range the results of the tensile tests of the plain bars were corroborated. Riveted joints at 200 degrees showed less strength than when cold; at 250 degrees and higher temperatures the strength exceeded the cold tests, and when overstrained, approaching the limit of rupture, at 400 to 500 degrees there was found when completing the test cold an increase of strength over the duplicate cold test made in the ordinary manner. A single riveted butt joint tested at 500 degrees ruptured with 81,050 lbs. per square inch on the net section of plate, whereas the corresponding joint tested cold failed in the same manner with 65,000 lbs. per square inch. Another joint at 500 degrees reached 119,980 lbs. per square inch compression on the bearing surface of the rivets. Still another joint, which was strained at 500 degrees, then cooled to 150 degrees and ruptured, sustained 137,110 lbs. per square inch compression on the bearing surface of the rivets.

As none of these joints failed by direct crushing of the metal at the bearing surfaces, without defining the crushing limits under these conditions of test, we are enabled to say the metal is capable of sustaining very high compressive stresses in this zone of temperature.

Rivets which sheared cold at 40,000 to 41,000 lbs. per square inch at 300 degrees sheared at 46,000 lbs. per square inch; and at 600 degrees, the highest temperature at which joints were ruptured failing in this manner, the shearing strength was 42,130 lbs. per square inch.

The internal strains in some oil-tempered and annealed steel cylinders have been investigated. The cylinders were numbered 7, 8, and 21.

The salient features of the investigation were that cylinder No. 7, which was oil-tempered, annealed, and then retempered, was found to have the entire surface metal, exterior bore, and ends in an initial state of compression, and the interior of the mass in a state of tension. The maximum stresses found were 47,161 lbs. per square inch compression, and 938 lbs. per square inch tension. The latter stress not representing, however, the maximum amount which was in the cylinder when entire, the inaccessibility of the tensile metal at the time preventing that value being ascertained. The strains in cylinders Nos. 8 and 21 were of small magnitude, showing the final process of annealing to have been very efficient. The middle section of cylinder

No. 8 was cut into two slices and each re-treated at Watertown Arsenal: the earlier treatment was done at the steel works. Slice No. 1 was heated cherry-red and quenched from the bore with oil at 65 degrees Fahr. Slice No. 2 was heated bright-red and cooled from the bore with water at 80 degrees. The maximum stresses in slice No. 1, computed from the strains which were released when the slice was cut into detached concentric rings, were 18,984 lbs. per square inch tension, and 34,669 lbs. per square inch compression, the compressive strains being next the bore. The maximum stresses in slice No. 2 were 50,814 lbs. per square inch tension, and 59,060 lbs. per square inch compression,—a total range of 109,874 lbs. per square inch in the same piece of metal. The compressive stress exceeded the primitive elastic limit of the metal. Even this is not all, for the observed stresses were the means for their respective rings, the rings which were cut apart radially showing additional strains not released until then. The inside ring of slice No. 1 was turned down in the lathe, reducing its exterior diameter in successive stages each, until its thickness had been reduced from .25″ to .05″ thick; in the meantime the bore continued to expand at each operation until the stress corresponding to the strain released was 50,720 lbs. per square inch, against 34,669 lbs. per square inch displayed by the entire ring. The ring was then turned down to .025″ thickness and cut apart radially, whereupon the ends opened .147,″ thus showing that a difference of intensity of stresses remained in this thin ring. Retrogression of intensity of strains occurs very rapidly when departing from the quenched surfaces. Observations were made on the persistence of internal strains under higher temperatures. Detached rings from cylinder No. 7 were cut apart at one side, the ends wedged apart, and the rings then exposed to the annealing effect of different temperatures. The wedge was driven until the elastic limit was exceeded, as shown by the permanent set in the chord measurement across the cut. In this condition the ring was under the maximum internal strains which it was capable of receiving at atmospheric temperature. The additional permanent sets observed on the chord measurement indicated the release of internal strains after exposure to higher temperature. Strains were released at 428 degrees, and increased sets found as higher temperatures were employed. The highest temperature reached was about 1,450 degrees. This temperature did not entirely eliminate

the internal strains, the restoration in chord measurement which followed the removal of the wedge after this temperature showed the metal had an appreciable elastic limit at that temperature, although a low one. This same ring was next heated cherry-red and quenched in oil. Now, subjecting it to the temperature 410 degrees, wedged apart substantially the same amount as before, and the permanent set found was over six times the magnitude of the set after heating to nearly the same temperature in the first instance. This remarkable difference in the persistence of internal strains displayed by the ring before and after the last retempering demands further investigation in order to ascertain the influence of intervening periods of time, of different initial states of hardness, and different methods of tempering and hardening.

Specific gravity determinations with sectors from cylinder No. 7 (the pieces were small, weighing in air about 33 grammes each) showed, after heating cherry-red and quenching in oil, a slight increase in density, and when quenched in water from the same temperature a decided loss in density. Again heating cherry-red, and reversing the pieces in the quenching fluids, the same differences were displayed as before, that is, quenching in oil caused an increase in density, quenching in water a decrease in density. Heating nearly white hot and quenching in oil caused a decrease in density, as the water had done at lower temperature. As similar treatment is found to cause in different specimens both internal strains and changes in density, these two features may be regarded as correlated functions.

From what has just been said we see that internal strains are released by elevation of temperature, and the extent to which they are released depends upon the temperature reached. Earlier remarks stated that the elastic limit diminishes with increase of temperature, therefore we infer that strains in excess of the elastic limit at the annealing temperature are released by that temperature, and complete elimination of internal strains would therefore require a temperature at which there was practically no elastic limit.

Phenomena attending the over-straining and alternate straining of iron and steel are under investigation. It appears that certain steel bars which originally possess an equality of elastic limits under tensile and compressive stresses, when loaded beyond the elastic limit in either direction, lose in the elastic limit in the opposite direction.

The loss has been found very serious, amounting in some cases to almost complete elimination of the elastic limit in the opposite direction to the over-straining load. Thus, a metal having elastic limits under tension and compression each 50,000 lbs. per square inch would have a total range of stress of 100,000 lbs. per square inch before overloading. Exceeding the tensile elastic limit, say, 1,000 lbs. per square inch, and there results a loss in the compression elastic limit, so that the total range of stress within the limits of perfect elasticity is now little if any above 51,000 lbs. per square inch. Bars over-strained in this manner have been annealed at different temperatures, from 1,180 down to 278 degrees.

The equality of elastic limits was measurably restored even by the lowest annealing temperature. Under the higher temperatures the restoration was nearly or quite complete.

MEETING 398.

Combination Voltmeter and Ammeter for Electrical Measurements.

BY MR. ANTHONY C. WHITE.

The 398th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, January 23d, at 8 P. M., Mr. G. W. Blodgett in the chair.

After the reading of the records of the previous meeting, the chairman introduced Mr. Anthony C. White, of the Bell Telephone Co., who read a paper on a "Combination Voltmeter and Ammeter for Electrical Measurements."

Mr. WHITE said: The phenominal growth of telegraphy, telephony, and electric lighting during the past few years has rendered more and more imperative the demand for accurate and commercial apparatus for measuring the various quantities involved in each of these branches of electrical engineering.

At the beginning of the present century the galvanic cell was discovered. This invention was of but very little commercial importance until the discovery of the Morse telegraph in 1837. The discovery of the carbon transmitter of telephony still further increased its value, and today there is no branch of electrical engineering of more importance than that of the galvanic or voltaic battery; yet, strange to say, there has been no commercial instrument in the market for measuring the electro-motive force and internal resistance of batteries up to the present time. The result has been that there is a vast amount of superstition afloat in regard to batteries, and, outside of a few electrical laboratories, absolutely nothing is known in regard to them.

In the fall of 1887 I began a series of tests upon various batteries, with laboratory apparatus, which led to the invention of the apparatus under discussion this evening. The electrical arrangement for determining the electro-motive force of batteries was the well-known Lacoine's method, which is as follows: —

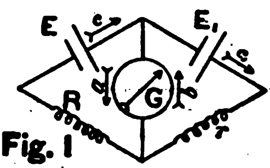


Fig. 1

In Fig. 1, E is a standard battery whose electro-motive force is already known. E_1 is the battery whose electro-motive force we wish to find. Let these letters also represent the electro-motive forces of these batteries, respectively. R represents a fixed resistance; r, a resistance which we can vary at will. G is a galvanometer. The battery E tends to send a current through the galvanometer in the direction indicated by the arrow A, tending to cause a deflection of the galvanometer needle, say to the right. The battery E_1 tends to send a current in the opposite direction, indicated by the arrow B, tending to cause a deflection of the galvanometer needle to the left. When both batteries are acting upon the galvanometer, its needle will be deflected to the right or to the left, according to which of these tendencies is the stronger. It is evident that the current that the compared battery E tends to send through the galvanometer can

be varied at will by means of the adjustable resistance r. Let us make r such that these two tendencies shall be equal. Then there will be no current through the galvanometer, and its needle will remain undeflected. In this case C, the current delivered by the standard battery, must be equal to C_1, the current delivered by the compared battery. Furthermore, the points C and D being at the same potential, since there is no current through the galvanometer, may be connected by a wire of 0 resistance. But in this case, from Ohm's law,

$$C = \frac{E}{R} \qquad C_1 = \frac{E_1}{r}$$

And since $C = C_1$

$$\frac{E}{R} = \frac{E_1}{r} \therefore E_1 = \frac{r}{R} E$$

Or, since E and R are both constants depending upon the electromotive force of the battery used as a standard and the number of ohms chosen for the fixed resistance, we may write,

$$E_1 = ar$$

where a is some constant.

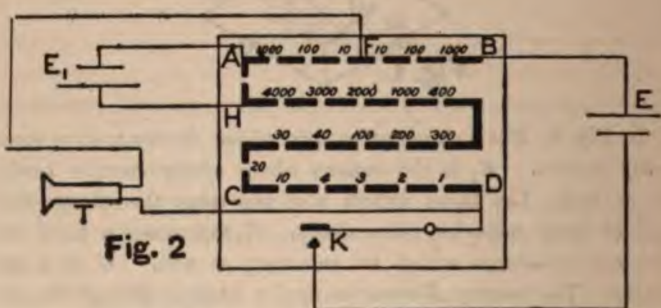


Fig. 2

Fig. 2 represents the apparatus as originally set up for measuring the electro-motive forces of batteries. A, B, C, D represents an ordinary Wheatstone's bridge. The standard battery, together with a key, is placed in circuit between B and D. The compared battery is connected so as to bridge around the infinity point at $A\ H$. One terminal of a telephone receiver is connected to D, the other terminal being left open. 1,000 ohms is thrown in at B for the fixed resist-

ances, all the other plugs between A and B being inserted. Resistance is then introduced in the variable side of the bridge, so that upon closing the key K no click is heard in the receiver when the telephone circuit is closed between D and F. The theoretical arrangement is shown in Fig. 3.

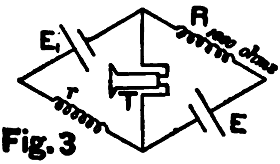


Fig. 3

This is obviously a similar arrangement to that described before, for R, the fixed resistance, controls the current delivered by the standard battery, and the variable resistance r controls the current given by the compared battery.

The apparatus that we then used for determining resistances of batteries was constructed upon the well-known Mance's method, but since it has no special bearing upon the apparatus which I shall describe tonight for this purpose, we will give it no further consideration.

Let us now discuss more in detail Lacoine's method of determining electro-motive force. From Figs. 4, 5, 6, and 7 it will be seen that there are four ways in which the galvanometer resistances and batteries can be grouped.

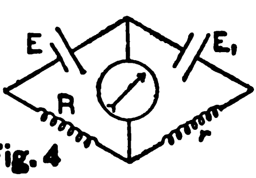


Fig. 4

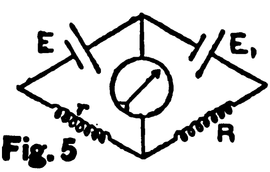


Fig. 5

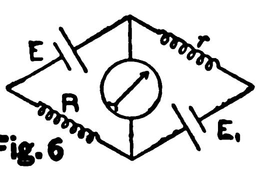


Fig. 6

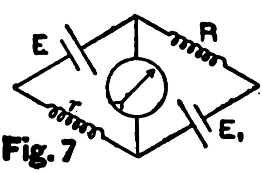


Fig. 7

In Fig. 4 the effect of the standard battery upon the galvanometer is determined by the fixed resistance, and that of the compared battery by the variable resistance, the galvanometer being connected between the medial point of the two batteries and the juncture of the two resistances. As we have before proven, the current delivered by each battery is the same when there is no current flowing through the galvanometer, and we can write:—

$$\frac{E}{R} = \frac{E_1}{r}$$

Therefore, $E_1 = \frac{E}{R} r = ar$

Fig. 5 represents the case where the fixed resistance is placed in the compared battery circuit, and the variable resistance in the standard battery circuit, the galvanometer being connected as before. When there is no current through the galvanometer we can write as above, $\frac{E}{r} = \frac{E_1}{R}$

Therefore, $E_1 = E\,R\frac{1}{r} = b\frac{1}{r}$ where b is some constant. From this formula we see that E_1, the electro-motive force we are measuring, will vary inversely to the variable resistance.

To illustrate the radical difference between these two combinations, let us take for our standard battery the Daniell's cell of 1.1 volts electro-motive force, and for our fixed resistance, R, 1,000 ohms. Suppose, now, the galvanometer remains at 0 when there are 200 ohms in the variable resistance, r. Then, if our electrical connections are as represented in Fig. 4, we have for the value of E_1 the unknown electro-motive force,

$$E_1 = \frac{E}{R} r$$

$$E_1 = \frac{1.10}{1000} \times 200 = .22 \text{ volts.}$$

On the other hand, if the arrangement is such as represented in Fig. 5, the unknown electro-motive force would be, under the same conditions,

$$E_1 = E R \frac{1}{r} = 1.10 \times 1000 \frac{1}{200} = 5.5 \text{ volts.}$$

Referring to Figs. 6 and 7 it will be seen that the electrical connections in Fig. 6 are similar to those in Fig. 4, the functions of R and r being the same in both cases, and the formula representing the value of E_1 is the same as in Fig. 4.

$$E_1 = \frac{E}{R} r$$

Also, the resistances in Fig. 7 fill the same office as in Fig. 5, and we have for the value of E_1, as in Fig. 5,

$$E_1 = E R \frac{1}{r}$$

Let us now discuss these two different applications of Lacoine's method of measuring electro-motive force, to determine their relative defects and advantages. Let us assume that we are limited to an ordinary Wheatstone's bridge, with coils ranging from 5,000 ohms to 1 ohm, the sum total being 10,000 ohms. For very accurate work I have considered it advisable to use as high a value for the fixed resistance as 10,000 ohms, and we will also assume that our standard is a Daniell's cell of 1.1 volts, and that we are measuring a storage battery of 2.2 volts. Then, if we have the arrangement shown in Fig. 4,

$$E_1 = \frac{E}{R} r$$

Or, $2.2 = \frac{1.10}{10{,}000} r$, whence $r = 20{,}000$ ohms.

But our Wheatstone's bridge only gives us 10,000 ohms, and we should be unable to measure so high an electro-motive force with the coils at our disposal.

With connections given as in Fig. 5, we should have with the same data: —

$$E_1 = E R \frac{1}{r}$$

Or, $2.2 = 1.10 \times 10{,}000 \times \frac{1}{r}$, whence $r = 5{,}000$ ohms.

With this arrangement, then, it is comparatively easy to measure high electro-motive forces with the ordinary Wheatstone's bridge where the customary arrangement would fail.

On the other hand, suppose the electro-motive force to be measured was .22 volts instead of 2.2 volts, then we have in the first case:

$$.22 = \frac{1.10}{10,000} r \quad \text{From which } r = 2,000$$

Consequently we are within the range of the Wheatstone's bridge. With connections shown in Fig. 5 we have

$$.22 = 1.10 \times 10,000 \times \frac{1}{r}. \text{ From which } r = 50,000 \text{ ohms,}$$

and we are beyond the capacity of the bridge. Consequently, it is comparatively easy to measure low electro-motive forces with the ordinary arrangement, where the special case would be outside the range of the Wheatstone's bridge. I have employed a 4-point switch for changing from one method to the other, and have found it entirely satisfactory.

Neither of these combinations are direct-reading, however. In the first we are obliged to multiply the variable resistance by a constant to obtain the required *E, M, F.* In the second we have to divide a constant by the variable resistance. Is it possible to make a direct-reading voltmeter out of either or both of these methods? Let us take the first arrangement, where

$$E_1 = \frac{E}{R} r = ar$$

If we make R of such a value that $\frac{E}{R}$ shall be unity, or some decimal of unity, so that a becomes 1, .1, .01, .001, etc., then it is evident that all that will be necessary to obtain the value of E_1 will be to change the decimal point of r. For instance, suppose our standard battery has an electro-motive force of 1.43 volts, and we make the value of R 1,439 ohms. Let us compute the values of the variable coils that will make the voltmeter direct-reading. For one volt we have:

$$E_1 = \frac{E}{R} r$$

$$1 = \frac{1.43}{1,430} r \;\therefore\; r = 1,000 \text{ ohms.}$$

And since E_1 varies directly as r, we can construct our coils thus:

1.00	volt	corresponds	to	1,000	ohms	in the	variable	resistance.
.50	"	"	"	500	"	"	"	"
.20	"	"	"	200	"	"	"	"
.20	"	"	"	200	"	"	"	"
.10	"	"	"	100	"	"	"	"
1.05	"	"	"	50	"	"	"	"
.02	"	"	"	20	"	"	"	"
.02	"	"	"	20	"	"	"	"
.01	"	"	"	10	"	"	"	"

Consequently, if we construct a voltmeter with variable resistance coils of these values, we shall have a direct-reading instrument reading from 0.01 to 1.00 volt. To make this method direct-reading it is not necessary to make the value $\frac{E}{R}$ some ratio of unity, although this is the simpler way. For instance, suppose we compute the value of r which would make E_1 unity, the standard battery and fixed resistance having been chosen beforehand. Let us assume our fixed resistance R is 1,375 ohms, and our standard battery 1.1 volts; then we have for the value of r for one volt:

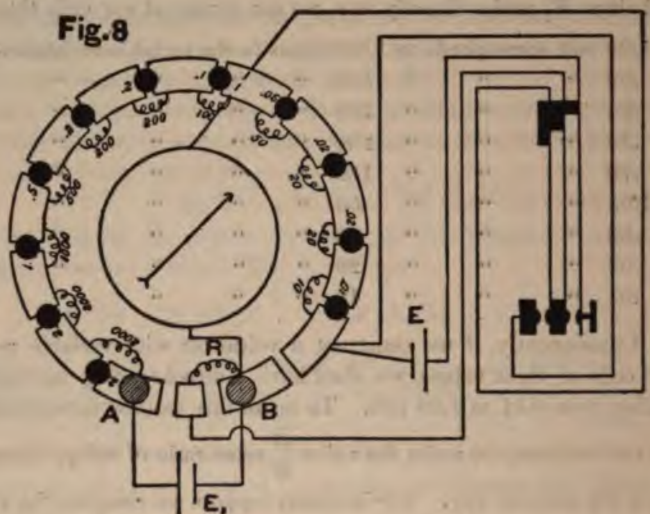
$$1 = \frac{1.1}{1,375}r, \text{ from which } r = 1,250.$$

Then we could build a direct-reading voltmeter by making the variable resistance coils as follows:

For	1.00	volt,	1,250	ohms.
"	.50	"	625	"
"	.20	"	250	"
"	.20	"	250	"
"	.10	"	125	"
"	.05	"	62.5	"
"	.02	"	25	"
"	.02	"	25	"
"	.01	"	12.5	"

In a direct-reading voltmeter constructed upon this principle the electrical connections and resistances would be as shown in Figs. 8, 9, and 10.

Fig. 8



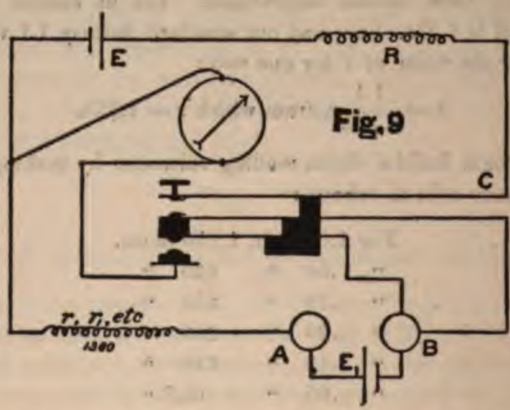


Fig. 9

We will assume that our standard battery has an electro-motive force of 1.36 volts, and that our fixed coil has a resistance of 1,360 ohms. Let us build our voltmeter to measure electro-motive forces from 6 to .01 volts. Then our variable resistance coils will be 2,000, 2,000, 1,000, 500, 200, 200, 100, 50, 20, 20, and 10 ohms, respectively, corresponding to 2, 2, 1, .5, .2, .2, .1, .05, .02, .02, and .01

volts. The terminals of the source of electro-motive force to be measured are connected, the positive to terminal A, and the negative to terminal B. The main circuit is opened at some point, C, and the terminals connected to the upper contacts of a double contact key. The galvanometer circuit is opened and the terminals taken to the lower contacts of the key. In this manner the standard battery circuit is kept open until the key is depressed.

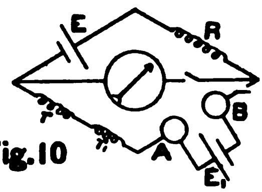


Fig. 10

Let us see if a direct-reading voltmeter can be constructed upon the principle of the special case where $E_1 = E\,R\frac{1}{r}$. We will give to the fixed resistance R, as before, such a value that the product ER shall be unity or some decimal of unity, for instance, 1,000. Then for

1.00	volt,	r =	1,000	ohms.
.50	"	"	2,000	"
.20	"	"	5,000	"
.20	"	"	5,000	"
.10	"	"	10,000	"
.05	"	"	20,000	"
.02	"	"	50,000	"
.02	"	"	50,000	"
.01	"	"	100,000	"

But a voltmeter built in this manner, of coils ranging from 1,000 ohms to 100,000 ohms for the fixed resistance, would not be direct-reading. For instance, suppose the battery to be measured had an electro-motive force of .7 volt, the resistance would be intermediate between 1,000 and 2,000 ohms, but we have no such coils or combination of coils that would give the desired resistance.

One way to obtain a direct-reading voltmeter with this arrangement is to make a slide resistance out of our variable coils, requiring for a range from 1 volt down to .01 volt 100 distinct coils and over 100,000 ohms resistance. We could in this manner make a direct-

reading instrument, but it would be difficult of construction as well as expensive.

BATTERY RESISTANCE.— In all battery work it is necessary to know the resistance, as well as electro-motive force of the battery. For this purpose the battery whose resistance we wish to measure is connected to a working resistance, and the electro-motive force at its terminals measured, its electro-motive force on open circuit having been previously determined. These two measurements enable us to compute its resistance. Let B represent a battery shunted by the resistance R. Let r represent the resistance of the battery. Let E represent the electro-motive force of the battery on open circuit, and E_1 the electro-motive force at the terminals of the battery when shunted by the resistance R. From Ohm's law we have

$$E = (R + r)\,C;\; E_1 = RC, \text{ from which, } C = \frac{E}{R+r} = \frac{E_1}{R}$$

And by transposition and reduction we have $r = \dfrac{E - E_1}{E_1} R.$

Therefore, we can obtain the resistance of the battery by subtracting its electro-motive force on closed circuit through R ohms from its electro-motive force on open circuit, dividing the remainder by the smaller electro-motive force, and multiplying the result by the resistance of the working circuit. By making the resistance of the working circuit equal to 10 ohms the process is very much simplified. It is necessary to get the value of E_1, the electro-motive force upon closed circuit, upon the instant of closing the circuit through the working resistance on account of polarization. To do this by means of the direct-reading voltmeter it will be necessary to use a triple contact key, and provide some means of opening the 10-ohm coil when not in use. It may also be desired to keep the 10-ohm coil closed for a definite length of time around the battery terminals without the use of the key. This is effected thus (see Fig. 11):

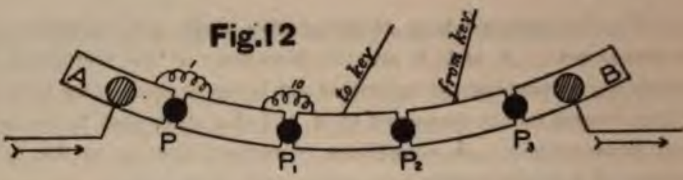
Fig. 11

S is the battery whose electro-motive force and resistance is to be measured. A and B are the terminals of the voltmeter, the remaining portions of the voltmeter not being shown. One terminal of the 10-ohm coil is connected to A, and the other goes to the adjacent brass strip a. A connection is carried from a to the upper contact of a triple contact key, and a lead taken back to the second strip b. With plug P removed it will be seen that when the triple contact key is depressed, the 10-ohm coil will be introduced between terminals A and B, and with plugs P and P_1 inserted the 10-ohm coil can be kept in circuit around the terminals of the battery for any desired time. With plug P_1 removed the 10-ohm coil is evidently inoperative. This arrangement accomplishes, then, the three ends desired, and we have combined in one instrument both a voltmeter and an instrument for determining the internal resistance of batteries.

AMMETER.— In many cases we do not care to know the electro-motive forces of batteries, or their resistances, but a quantity dependent upon both of these factors. We wish to know the current of electricity which they will send through a given resistance. It is also of great value to know the current flowing through a given system, say a telephone transmitter, an incandescent or an arc lamp. The addition of one more coil to the instrument, as described, will convert it into a direct-reading ammeter, the figures before denoting volts now registering amperes.

Let us see how this is accomplished. From Ohm's law it follows that if we have a current of one ampere flowing through one ohm, it will generate a difference of electric pressure of one volt at the terminals of this resistance. Now, if between the terminal A and B of our voltmeter we connect a 1-ohm coil, and if we send a current of one ampere through it, the voltmeter will register one volt. Conversely, if our voltmeter registers one volt we know that a current of one ampere is flowing through the circuit of which the 1-ohm coil forms a part. This coil should be placed in our combination instrument above described, adjacent to the 10-ohm coil, added for battery resistance measurements, the connections being as shown in Fig. 12.

Fig. 12



A and *B* represent, as before, the terminals of the voltmeter proper. By inserting plugs P_1, P_2, and P_3; *P* being removed, it is apparent that we have one ohm from *A* to *B*. We have, therefore, with the additional 1-ohm coil, three instruments combined in one, a voltmeter, an ammeter, and an apparatus for measuring the internal resistance of batteries.

HIGH VOLTAGE.— It is perfectly practicable to extend our voltmeter to high voltages. For ordinary battery work a range from .01 to 6 volts is all that is necessary, the coils required for the variable resistance being 10, 20, 20, 50, 100, 200, 200, 500, 1,000, 2,000, 2,000 ohms. To extend the range to 100 volts five additional coils would be required of 5,000, 10,000, 20,000, 20,000, and 50,000 ohms, respectively. The only objection to the use of these coils is the expense of the wire, which would be considerable for such high resistances. To obviate the necessity of employing these coils for high voltage I have substituted the following device (Fig. 13).

Fig. 13

An auxiliary coil of 990 ohms is added to the apparatus. One end of this coil is connected to the *A* terminal of the voltmeter proper, and the other end is connected to the isolated binding post *C*. The terminals of the source of electro-motive force that we wish to measure are connected to this binding post and the *B* binding post of the voltmeter. The plugs between *A* and *B* are arranged so as to throw the 10-ohm coil in circuit between *A* and *B* when the key is depressed.

This is the same arrangement that would be used in the second measurement for battery resistances.

It is evident that we have in circuit between the terminals B and C 1,000 ohms when the key is depressed, and that there are 10 ohms of this resistance included between the terminals of the voltmeter proper. Consequently, $\frac{1}{100}$ part of the electro-motive force between the terminals B and C will be included between A and B. It follows that if we measure the electro-motive force between A and B by our voltmeter proper under these circumstances, and multiply this voltage by 100, we shall have the total electro-motive force between B and C. It is only necessary, then, for high voltages to use terminals B and C, and to move the decimal point of the voltmeter reading two places to the right.

RANGE OF THE APPARATUS.—We can with perfect safety measure up to 200 volts in this manner, by properly constructing our 990-ohm coil and the 10-ohm coils, but for higher voltages it is better to sacrifice somewhat on our battery resistance measurements, and make the connections thus (Fig. 14):

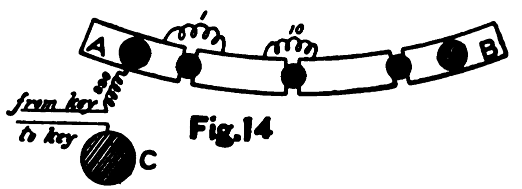


Fig. 14

In this manner any slight resistance which might be introduced by oxidation of the contacts from sparking at the key would be thrown into the 990-ohm coil rather than into the 10-ohm coil. The instrument could still be used for determining battery resistance, the 10-ohm coil being introduced manually.

The following data will indicate how the range of the instrument can be extended so as to cover any voltage used commercially, even those employed in arc lighting. It is evident that some of the values given cannot be realized in practice, but there is no difficulty in selecting a combination that will cover every case desired.

Fixed resistance R, 1,000 ohms + or —

Variable Resistances.	9990-Ohm Coil. 10-Ohm Shunt.	4990-Ohm Coil. 10-Ohm Shunt.	2490-Ohm Coil. 10-Ohm Shunt.	1990-Ohm Coil. 10-Ohm Shunt.
Ohms.	*Volts.*	*Volts.*	*Volts.*	*Volts.*
2,000	2,000	1,000	500.0	400
2,000	2,000	1,000	500.0	400
1,000	1,000	500	250.0	200
500	500	250	125.0	100
200	200	100	50.0	40
200	200	100	50.0	40
100	100	50	25.0	20
50	50	25	12.5	10
20	20	10	5.0	4
20	20	10	5.0	4
10	10	5	2.5	2

Fixed resistance R, 10,000 ohms + or —

Variable Resistance.	9900-Ohm Coil. 100-Ohm Shunt.	4900-Ohm Coil. 100-Ohm Shunt.	2400-Ohm Coil. 100-Ohm Shunt.	1900-Ohm Coil. 100-Ohm Shunt.
Ohms.	*Volts.*	*Volts.*	*Volts.*	*Volts.*
10,000	100	50.0	25.00	20.0
5,000	50	25.0	12.50	10.0
2,000	20	10.0	5.00	4.0
2,000	20	10.0	5.00	4.0
1,000	10	5.0	2.50	2.0
500	5	2.5	1.25	1.0
200	2	1.0	.50	.4
200	2	1.0	.50	.4
100	1	.5	.25	.2
	210	105.0	52.50	42.0

99900-Ohm Coil. 100-Ohm Shunt.	49900-Ohm Coil. 100-Ohm Shunt.	24900-Ohm Coil. 100-Ohm Shunt.	19900-Ohm Coil. 100-Ohm Shunt.
Volts.	*Volts.*	*Volts.*	*Volts.*
1,000	500	250.0	200
500	250	125.0	100
200	100	50.0	40
200	100	50.0	40
100	50	25.0	20
50	25	12.5	10
20	10	5.0	4
20	10	5.0	4
10	5	2.5	2

Used as an ammeter by the employment of a 1-ohm coil, we have seen that its range is from .01 to 6 amperes, and where the introduction of 10 ohms into the circuit is not objectionable, the 10-ohm coil used for battery tests can be employed in place of the 1-ohm coil, and the range would be in this case from .001 to .6 amperes. The following data give the range of the instrument with various coils:

10.0000	ohm-coil.	Range	.001	to	.6	amperes.
1.0000	"	"	.010	"	6.0	"
.1000	"	"	.100	"	60.0	"
.0100	"	"	1.000	"	600.0	"
.0010	"	"	10.000	"	6000.0	"
.0001	"	"	100.000	"	60000.0	"

These figures are somewhat delusive, however. For instance, take the .001 ohm-coil, 6,000 amperes would cause a waste of 36,000 watts, or 48 electrical horse-power, in our voltmeter alone. On the other hand, we could easily measure 1000 amperes with this coil properly constructed, the loss in this case being only a little over one horse-power. An intelligent use of the above coils will enable us to cover nearly every case in practice. For special work a more delicate galvanometer, enabling us to measure to .0001 volt, might be employed. It is evident, then, that the apparatus can be constructed so as to cover any range of current strength or electro-motive force desired.

In criticism of the instrument the objection might be raised that there is no battery of sufficient constancy to be employed with the apparatus. It will be observed, however, that it is not necessary to use a standard battery, but only one that shall remain constant for a considerable time. The best battery to employ would be some form of Daniells cell, were it sufficiently portable. I have used a modification of the Daniells cell for two years with a stationary battery testing apparatus of this type with perfect success. A comparison of the battery with the Latimer-Clark cell at various times has shown a variation of less than one per cent. For convenience, however, it is necessary to use some form of dry battery. I first used a chloride of silver battery of about 20 ohms internal resistance, but found its resistance to be too variable for the desired accuracy of one per cent.

The cell that I am now using has a resistance of two ohms, and has been entirely satisfactory up to the present time. To check the accuracy of the instrument all that is necessary is to have at your disposal a Daniells cell. Should you have any reason to suppose that your instrument is out of adjustment measure the electro-motive force of your Daniells cell by it, and should it differ from the known value of the electro-motive force of this cell, add or remove from the adjusting coil a few inches of wire until you get the desired reading of your voltmeter.

From my own experience with the instrument I think this adjustment will seldom be necessary.

MEETING 399.

Electrical Purification of Sewage.

BY MR. FRANK M. GILLEY.

The 399th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, February 13th, at 8 P.M., Prof. T. M. Drown in the chair.

After the reading of the records of the previous meeting, the chairman introduced Mr. Frank M. Gilley, of Chelsea, who read a paper on "Electrical Purification of Sewage."

Mr. GILLEY said: The treatment of sewage was attempted over a century ago, and the chemicals employed at that time were almost identical with those in use today, sulphate of iron and lime. England has lead in this work. Her cities are so populous and near together that the introduction of systems of drainage removed a nuisance farther down the stream. Rivers, or streams as they would be less pretentiously called, became filled with sewage deposit, the fish in them died, and the general poor health and discomfort of those who lived

on or near the banks called attention to the absolute necessity of removing or abating such nuisances. The removal consisted in the application to land or the discharge of the sewage into the sea or farther down the brook or river flowing through the town, perhaps near some other town. In many cases the nuisance was abated, never removed entirely, by the use of chemicals, and the precipitation of most of the suspended matter, and the destruction or oxydation of a little of the organic matter in solution. Suspended matter must either be deposited in settling tanks as sludge or in some river or harbor as mud until dredged out. The organic matter is the most difficult to destroy or remove, and is the part most dangerous to health. The oxydation of the organic matter can be accomplished by one method only, chemical action, whether that be produced by filtration, the addition of chemicals, or electrolytic action. A filter is sufficient when employed intermittently, for then the filtering material becomes aerated, *i. e.*, charged with atmospheric oxygen during the periods of rest, and this oxygen destroys the organic matter of the sewage. Oxydation can also be accomplished more or less expensively by chemicals. The electrical method differs from the above methods in two points; first, the oxygen and chlorine that produce the burning up or oxydation of the organic matter is made by decomposing, by the aid of a current of electricity, the water and chlorides of the sewage itself; second, the oxygen and chlorine act much more powerfully at the moment of their formation, being set free in what is called a "nascent" state.

Mr. Wm. Webster, F.C.S., engineer and contractor for the construction sewage works, including precipitation tanks, during a series of successful experiments in the purification of sewage by electrolysis, settled at last upon two metals suitable for electrodes, aluminum and iron, the latter, on account of its cheapness, practical on a commercial scale. He first tried large tanks in which the liquid was treated and allowed to settle.

Strips of sheet iron are placed in a jar of sewage and a current passed through the solution. Hydrogen is given off from the plate connected with the zinc pole of the battery, and from the positive pole, *i. e.*, the strip where the current enters, chlorine and oxygen are set free in a "nascent" state, probably combining with the iron to form a hypochlorite of iron which is immediately reduced to ferrous car-

bonate and oxide. If there be no dissolved *O* in the water the white oxide is produced. But in any case the color is soon green, and finally red, ferric oxide (Fe_2O_3). On a small scale, or where there is no current or agitation, the precipitate buoyed up by the hydrogen is brought to the top together with the particles in suspension, and finally sinks. If overtreated, the fitrate or effluent, as the clear liquid is called, has a reddish tint from the presence of ferric oxide. The solid matter, or sludge, has little or no liability to decompose, but, of course, must be disposed of in some way, ploughed into land, pressed and sold or given away as a fertilizer, or taken out to sea.

The E. M. F. between the plates is at least .9 volt when of iron, 1.5 when of carbon. In practice London sewage requires one ampere per gallon for 10 minutes, or less than $\frac{1}{4}$ ampere an hour per gallon. More current would supercharge the liquid with iron salts. A slight greenish tinge and evident separation of the suspended matter are the signs of sufficient treatment. The color on leaving the sewer is nearly white and opaque. After treatment the *liquid* is clear and filled with the particles of sludge, which deposit quickly when allowed to rest for a few moments. Owing to the resistance of contacts and the liquid itself, about 2 volts is the difference of potential of the plates, and about 1 ampere per 5.5 square feet of iron surface exposed. In larger units, 23 h. p. in 24 hours treat 7,000,000 gals. of London sewage.

It may be advisable to pass the effluent through an electric filter composed of alternate layers of coke carbon and sand or porous earthenware, the coke being electrically connected in alternate sections to positive and negative terminals of a dynamo. No increased power is required, for when the electrical filter is used the treatment with the iron plates is not carried so far. The same device is also applied to household filters for drinking water, the contamination of which with sewage or vegetable organic matter is always to be feared, and water of purity as regards organic matter and living organisms produced easily. A few open circuit cells furnish sufficient current which, on account of the resistance of the water, is small and does not flow at all while the filter is not in use.

Where brackish or salt water can be obtained by the means of a porous diaphragm, a disinfecting fluid containing 18 grains chlorine per ampere per hour is made. The positive plate must be of carbon, the negative may be of iron. If in the porous jar containing the car-

bon a piece of iron be connected also, a hypochlorite of that metal is made and may be used for the same purpose as the chlorine alone. One-third grain of chlorine is found to disinfect one gallon London sewage. By automatic attachments such an apparatus is used in the household, and the liquid supplied and drawn off at intervals when needed for use. The ordinary Leclanché cells, five or six in number, will last several months and produce two gallons of chlorine solution daily.

Mr. Webster's experimental station is located at Crossness about 13 miles from London. The sewage is pumped into a shoot 18 inches square, 400 feet long, and filled with wrought iron plates in groups of 15, a large number of which connected in multiple or parallel form sections in series with each other. A space of two or three feet in the shoot between sections is sufficient to prevent undue leakage. The 70 h. p. Mather and Platt dynamo gives 20 volts. The six sections take approximately 3 volts per section, current 320 amperes. It would be economical as regards the loss in the conductors to have more sections in series, but the number is limited to 25 or 30 on account of danger to the workmen, it being impossible to avoid grounds, as both ends of the shoot have liquid connection to the earth at the inlet and outlet. The consumption of the iron plates is from 1 to 2 grains per gallon of sewage treated if cast iron is used. Wrought iron scales badly and is more expensive, but from its lightness is well adapted to experimental work. The velocity in the shoot is about 10 to 25 feet a minute, or from 4,000 to 10,000 gallons per hour. The color shows no apparent change for 20 to 30 feet, then numerous bubbles come to the surface, and farther on these have a brown color, and near the end the liquid is dark. At points in the shoot the current runs over or under an adjustable board, giving a thorough mixing and a complete control of the level in each section of the shoot. It is desirable that the outlet should be below the level of the liquid in the precipitating tank that it may settle rapidly and to a compact form. As the churning action in the shoot has liberated all of the hydrogen, the precipitate settles at once, and in two hours the clear effluent may be drawn off and discharged directly or through an electric filter into any convenient stream; or without settling it may be run on to land which does not become clogged, and the precipitate or sludge rapidly drying on the surface is easily worked into the land. The sludge as

taken from the tanks forms .7 per cent of the total sewage, and, after remaining in a settling tank, is reduced to .4 per cent of the original amount treated. It then contains 90 to 95 per cent of water, and must be disposed of in some way. Deprived of 50 per cent of this water by presses (and the sludge formed by electrical treatment is better adapted than any other for the press), and 20 per cent more by drying, it is worth, by analysis, $10 per ton, but in any case should pay for carting.

Cast iron is thought to have an advantage over wrought iron in the larger per cent of carbon it contains, which results in the production of chlorine. The size is limited only by the possibilities of manufacture. Six feet by 3 feet by ¾ inch plates are said to be made for other purposes by French engineers. The metal dissolves evenly, any projecting portions offering less resistance and being more acted upon by the current. Though only ½ inch apart the plates showed no signs of blocking, and the entire shoot can be emptied in 15 minutes for cleaning.

A test at the time of my visit was in progress by the chemists of the London County Council, and the consumption of iron determined by weighing the plates before and after a long run, and analyses made of the crude sewage and effluent. It must be remembered that such a reduction of the organic matter is desired as shall abate the nuisance that exists in the river. Perfect purification, nor anything approaching that, is not desired. 70,000,000 gallons at Crossness, and 90,000,000 at Barking is a large amount to treat by any system, but the attempt is being made by the addition of 3.7 grains of lime and 1 grain of sulphate of iron per gallon, and the effluent disinfected by permanganate of soda manufactured at the works. The discharge is supposed to be at ebb tide, but takes place practically all the time that the water in the river is low enough. The manganate of soda and sulphuric acid are added just before discharge. Notwithstanding this treatment, complaints of the condition of the river are continually made. The amount of chemical used seems insufficient, for other cities used 10 to 20 grains instead of 5. But for all that between two and three million dollars is being spent on immense precipitating tanks at both the outfalls, with the view of extending the chemical treatment to the entire sewage discharge. These tanks, with some changes, can be made to serve for the electrolytic process of treatment when that is finally adopted.

The plant that Mr. Webster has built at Crossness to test his system is only relatively experimental, having a capacity of 500,000 gallons a day, and by extending or enlarging the shoots, 1,000,000 gallons, for which there is sufficient room and power. At 30 gallons per head per day this would be ample for a town of 30,000 inhabitants in England. In the United States the sewage is larger in quantity but more dilute, requiring larger shoots and more iron surface, *i. e.*, a somewhat greater first cost but about the same operating expenses. In England the cost of a 1,000,000 gallons a day works, with duplicate engines and dynamos and iron plates lasting ten years, is estimated at $30,000, or $1 per inhabitant, but would be materially less here, if the cost of steam and electrical machinery and contract construction work in the two countries furnishes any basis for comparison. The expense of 300 pounds of iron daily consumed has been estimated in the cost of the plant, and the labor of four men and the consumption of a ton of coal or less make a daily expense of $13. A visitor at the station is invariably impressed with the success of the system, no unpleasant odor is perceptible, and the appearance of the sewage during treatment and precipitation is far more inviting than the surface of the streets of the crowded parts of even Boston. The epicures of London may be looked upon as opposed to this system, for, according to Lawes, the fish of the Thames feed on the sewage; and where will the tempting and luscious whitebait, that is now taken only in the Thames estuary, and for which the cuisines of London are famous the world over, find its food and the dredgers find employment if the crude sewage is successfully treated by the electric current?

The paper was illustrated by numerous diagrams and lantern views.

MEETING 400.

Domestic Steels for Naval Purposes.

BY LT.-COM. J. G. EATON, U.S.N.

The 400th meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, February 27th, at 8 P.M., Prof. R. H. Richards in the chair.

After the reading of the records of the previous meeting the chairman introduced Lt.-Com. J. G. Eaton, U.S.N., who read a paper on "Domestic Steels for Naval Purposes."

Mr. EATON said: Within the scope of this paper lies properly a rapid retrospect of the history of domestic steels, with a view of understanding fully the marvelous development that has occurred within the past seven years. The uses we are to consider are those strictly germane to ships of war, and include not only hulls and hull material, but boilers, engines, rigging, guns, and armor.

Proceeding in chronological order we find that in 1865 the Pennsylvania R. R. Co. made efforts to secure flange plates of American steel for its locomotive boilers. The steel then used was crucible steel, made by a Pittsburgh firm. So satisfactory were the results that in 1866 this company built no less than eleven locomotive fire boxes of the same material. In June, 1866, was built the first locomotive boiler entirely of domestic steel, crucible made and of high cost. At this time the Bessemer process was but just established in the United States, and the open-hearth process not yet introduced. Despite the evident superiority of the new material, it was not until 1873 that steel wholly superceded iron for boiler purposes, even in this company.

In the navy a high grade of steel was used for steam launch boilers in 1872, but it was not until the spring of 1878 that the first large marine boiler of steel was placed on board the fish commission steamer "Lookout," and the "Nipsic" was the first American man-of-war to be thus equipped, in the fall of the same year.

For structural purposes crucible steel, hardened by an alloy of chromium, was employed in the Eads St. Louis bridge in 1869. Though successful in all respects, the experiment has not been repeated.

Practically, mild steel for bridge building dates from 1879, when Bessemer plates and girders were incorporated in the approaches to the East River bridge. From this date also open-hearth steels entered largely into bridge structures. None of the bridge steels of that time would now be called mild steel, as the T. S. was from 70,000 to 80,000 lbs. per square inch, and the elongation only 20 per cent in 8 inches. The total amount used was small, as the aggregate of all classes, crucible, open hearth, and Bessemer, was but 18,000 tons in the fifteen years from 1869 to 1884.

In ship building we did nothing whatever prior to 1879. In that year three vessels of an aggregate tonnage of 246 tons were built for river navigation. Up to 1883 five more, including lighters, were constructed. The total tonnage to this date was less than 500 tons. All of these vessels were steel plated only. Practically, then, steel ship building was an unknown art, the material untried, and the workmen unskilled, when the frame of the "Dolphin" was laid down in 1883.

Such was the status of the steel industries as regards structural material when Congress authorized the constructien of our four first ships of mild steel of domestic manufacture. The courage and foresight of the Advisory Board of Naval Officers, upon whose recommendation Congress acted, are entitled to recognition. Iron ship building was already an established industry, and its results certain. As to steel (this was in 1882), there were difficulties in production, as yet imperfectly understood, and but partly overcome. There was the still more serious objection of the utter lack of workmen skilled in the manipulation and assembling. The compelling reasons leading to the Board's decision are here given:—

1. Great saving in weight of hull, compensating for difference in cost.

2. Increased strength in hull.

3. Increasing success attending construction of steel hulls abroad.

4. The certainty that steel in the near future is to supplant iron in ship construction. (A prophecy virtually fulfilled.)

5. The impetus that such a step taken by the government would give to the general development of steel industries in this country.

6. The necessity that the new ships shall in all respects equal, if not excel, ships of other navies, class for class; and,

Finally, that for the reputation and the material advantage of the United States, it is a prime necessity to take a bold and decided step to win back from Europe our former prestige as the best ship builders in the world.

From these seven patriotic, courageous, and far-seeing conclusions the navy has never receded. The success of the new vessels has evidenced their wisdom, and the merchant marine has been quick to follow the initiative.

Quality and cost were undetermined factors. The specifications were high, and the requirements rigorous. Replying to circular letters, the manufacturers expressed confidence as to the quality of their steels, but doubted their ability to supply the special shapes required. It is a somewhat caustic commentary on the actual capabilities of the time that the quality failed, though sections were up to standard.

At this time the largest ingots were of five tons, the heaviest plates but $1\frac{1}{4}''$, weighing about three tons each. Thirty feet long I beams of $12''$ section almost stalled the heaviest rolls. At present the Bethlehem Iron Co., of Bethlehem, Penn., are casting ingots of 100 tons weight, and are producing curved plates $17\frac{1}{2}' \times 6' \times 17''$ thick, and $16' \times 9' \times 12''$ thick, weighing 36 tons each, finished. There are at least six other firms who are now prepared to furnish plates up to four inches in thickness.

The specifications which were drawn up in June, 1883, called for mild steel for hulls with T. S. of at least 60,000 lbs. per square inch, and elongation of not less than 23 per cent in eight inches. Boiler plates specified not less than 57,000 lbs. nor more than 63,000 lbs., with a ductility of at least 25 per cent.

Under these specifications contracts were entered into for the construction of the A, B, C, D ships in July, 1883. Three of these ships, the "Atlanta" and "Boston," of 3,000 tons displacement each, and the "Chicago," of 4,500 tons, have recently visited this port. Since then they have weathered storms of unusual winter severity in crossing the Atlantic, and are now in Europe. The D, the Dolphin, a dispatch boat of 1,500 tons, has recently refitted in New York, after

a voyage of over 45,000 miles around the world. That these ships have shown themselves equal in construction and material to the strains and service for which they were designed has been abundantly proved. During the construction of these vessels a determined effort was made to break down the system of naval tests and inspection. The reasons assigned were impracticability and expense. Delays were not only exasperatingly frequent, but failures also were many. The specification as to ductility was lowered to 21 per cent, and some slight modifications made as to methods. The system then established is the foundation of our present inspection. Each new vessel is built of better material than her predecessor, and the requirements keep in advance of the material. In 1886 the Steel Board succeeded the Advisory Board, and has for its function the inspection of all steel material for hulls and machinery.

Attention was called to tables on the board which showed the increasing severity of the specifications, and the changes due to experience.

In hull plates and shapes we find the tensility constant at 60,000 lbs., but the additional safeguards of chemical conditions and surface inspection, aided by additional tests, serve to show the good or bad quality of the material better than either T. S. or elongation.

Up to 1876 steel was generally accepted on the maker's guarantee. From that time, however, testing of steel, particularly boiler steel, came in. The features of the Pennsylvania R. R. Co.'s inspection, which are quoted as being the most thorough before the navy inspection began, were: —

1. Careful examination of every sheet for mechanical defects.

2. Tensile test; 55,000 lbs. per square inch, ultimate strength. Elongation; 30 per cent in 2 inches. Both of these were averages. The limits were: tensile, minimum 50,000 lbs.; maximum 65,000 lbs.; elongation, minimum 25 per cent.

3. Rejection of sheets developing defects in working.

4. Coupon tests for each sheet.

No conditions were imposed on impurities beyond those which the manufacturer knew would affect surfaces, and cold or hot shortening.

The inspection of steel for naval purposes contemplates that the inspector should thoroughly familiarize himself with the composition of the furnace charges. As the variations in the pig and mill irons,

blooms, crop ends, scrap, and ore that go to make up the charge are recorded in the resulting steels, the inspector should possess a fair knowledge of the chemical composition of each ingredient. Chemical analysis of the resulting heat is invaluable, but even this fails to give warning of certain conditions which can be presaged from the characteristic of some component charged. Forearmed with this knowledge, he may avail himself of the extra tests allowed at his discretion, and either justify his suspicions by patent proof and reject the heat, or assure himself that the material is good.

Acid open-hearth furnaces run two heats daily. Basic furnaces can as easily run four in the same time. A heat may contain three tons, or fifty tons of metal, according to the size of the furnace. The melted steel is usually tapped into a ladle previously heated, and thence into ingot molds. Ingots vary in weight from 500 lbs. to 200,000 lbs., and in cross-section from 2″ x 2″ to 50″ x 72″. They are either top-cast by pouring directly into the mold, or bottom cast by stand and runners. Whilst the heat is being turned, and near the middle time, tests are secured for chemical analysis. Tests may also be taken at the beginning and end. Should these tests exhibit wide variations, then each ingot must be tested independently. From the ingots the inspector selects the poorest four for his test plates. Here, as elsewhere, his duty is to secure the worst specimens, and make these his indices as to quality. The ingots chosen are taken to the heating furnaces and there raised to the proper working heat, determined by the heater's eye, the color ranging from a light yellow to white according to the per cent of carbon. This is a critical operation, as an overheated or burnt ingot will cause enlarged crystallizations, pits, and laminations in the finished product. Insufficient heating will either break the rolls or cause cold flow, setting strains in the plate or shape, which can only be restored to an amorphous condition by thorough after annealing. No amount of after mechanical work will reduce coarse crystallization.

SURFACE INSPECTION.—The plate or shape as it issues from the rolls should be inspected whilst still hot. Most surfaces are covered in a short time with red or black oxides and mill scale that effectually conceal serious defects. Pickling serves to bring these to light, but immediate detection not only safeguards any possibility of error, but obviates much unnecessary expense. The principal surface defects

are pitting, scabs or blisters, hair cracks, scale marks, snakes, cobbles, and laminations. Probably 75 per cent of surface defects are due to pits. Pits are conical cavities, base uppermost, pocking the surface. If their depth is at all considerable the plate is ruined. Their cause has already been stated. Should cinder or fine brick from the heating furnace be rolled in, a spotted appearance will give indication. A sharp tap of the long-handled hammer carried by the inspector will dislodge the extraneous substance, and disclose the extent of the injury. Bits of slag are discovered by hair lines. Scale cools more rapidly than the plate itself, and produces hummocks. Cracks are found in the direction of rolling, and indicate imperfectly welded blow-holes long drawn out. Test transverse specimens to ascertain their injury. Snakes, on the contrary, as their name implies, are twisted in every direction. Their appearance strongly resembles a water mark in paper, and they are visible only in favorable lights. They are, undoubtedly, caused by the presence of low forms of iron, peroxides, or protoxides, generated by burned metal in the furnace, and separate two masses of pure steel. No amount of work, heat or mechanical, will effect a true weld across this filmy barrier. Once in the ingot, snakes reappear inevitably in the plate or shape. An ingot known to be snaked is at once thrown aside to be scrapped. Snaked material is utterly lacking in homogeneity, and no material for structural, boiler, or engine purposes should be accepted which is even suspected of this defect. Crucible and basic steels are nearly exempt from this evil. Radiating furnaces should prevent them entirely.

Laminations occur at the surface and upon the edges. Surface laminations are due to chipping ingots, the cavity thus formed being covered by overlapping edges. A few taps of the hammer will cause these overlaps to separate into sheets. Plates should be inspected for laminations after shearing.

Cobbles are waves in a plate caused by unequal heating of the sides of an ingot. Under an equal draught from the rolls the hotter side creeps faster, thus producing ridges. There is no remedy for this defect. Cobbles are recognized by the diagonal trend of the ridges. Simple waves at right angles to the longitudinal axis are not serious. They are caused by unequal cooling on the train rolls.

SHAPES.— The surface inspection of bulb-beams, angle, T, and Z bars is much simpler than that of plates. The blooms, slabs, or

ingots from which they are rolled have smaller sections, permitting more even heating and better cleaning in the rolls. Unsymmetrical sections are found, and many run scant near the ends. In bulb-beams especially the angles are frequently cold drawn by the more rapid travel of the metal in the web, due to its receiving a great deal of work after the flange is fairly formed. Again, over 50 per cent of the metal is below the neutral axis of the web. The cold flow causes wire edges, and sets strains that in many cases equal the strength of the metal. A beam thus rolled might shiver to pieces, like brittle glass, on being thrown from a platform car. Proper annealing will do much to restore the metal to a state of intermolecular equilibrium. Unsymmetrical angle bars, 5″ x 3″, etc., also suffer from the same cause. To be absolutely certain that these strains are removed, annealing should be resorted to. The apparent loss in ultimate strength is more than compensated for by the gain in homogeneity.

TEST SPECIMENS.— The navy standard specimens for structural and boiler material are 16 inches long, not over 2 inches in width, with a cross-section of not less than five-tenths nor more than eight-tenths of an inch. The witness marks are 8 inches apart. For engine forgings, protective deck, ordnance and armor plate, a filleted round is prepared, section not over one square inch, and 2 inches between the witness marks. Other things being equal, this specimen will give 30 per cent greater elongation than were the witness marks 8 inches apart. Four test specimens are taken from each of the four test plates. This permits duplication in case of faults in the specimens themselves. Recalling that ingots are tapered to facilitate stripping, and that the bottom of the ingot has not only a greater cross-section, hence greater reduction and more work under the rolls, but also that the steel is more compressed and freer from sponginess at the bottom, the inspector takes these specimens from the top and sides. The object in view is to obtain specimens that shall show not the average condition, but the *poorest* part of the finished material. Here, as always, the inspector is on the alert for the worst features. There is no average strength for a steel plate. Its true strength is the value of the weakest inch of its contents.

Tensile strength and elongation vary in the same plate. Thus, a remarkably well rolled plate at the Homestead Steel Works at Pittsburgh rose from 49,000 lbs. T. S. at top end to 51,800 lbs. T. S.

at bottom end, or 6 per cent. The taper of this ingot gave 26 reductions for top end to 27 reductions for bottom. The elongation fell from 32.7 per cent at top to 29.8 per cent at bottom, or 10 per cent. The value of this plate was evidently the minimum in each case.

The larger the ingot the more essential the selection of specimens from the top. Segregation of the metalloids increases with increase of size, as large ingots, presumably, cool slowly. The temperature at which the heat is termed is, however, of greater importance. Surprising variations occur in chemical condition in same ingot. Thus, two specimens taken from the opposite ends of the same plate rolled from a slabbed ingot, and a slabbed ingot has already lost by shearing its worst end, gave: —

	T. S.	Elongation.	Reduction.	Carbon.	Phosphorus.
Top end, . .	64,500	19 per cent.	31 per cent.	0.31	0.075
Bottom end, .	55,400	26 "	48 "	0.17	0.050
Heat test, ...				0.15	0.044

A result sufficient to condemn at once the material for ship building. In cold bending the top specimen broke short off with fracture, indicating high carbon and phosphorus, and showing weak, large crystals. The bottom specimen closed upon itself without a crack.

TESTING SPECIMENS.—The test piece selected for breaking is carefully measured with a micrometer reading to thousandths of an inch. From this is computed the original section. Twelve one-inch marks are punched on the edges for elongation data. The specimen is then placed in the machine and the initial stress applied. Additional loads of 5,000 lbs. each are added at intervals of thirty seconds, the beam being kept in equilibrium. The elastic limit is marked by unsteadiness of the beam, ending in a sudden drop. The cracking of the mill scale at this instant is a good though not infallible indication. When the ultimate strength is reached the beam refuses to rise. After this the specimen stretches and necks, until fracture occurs, with a sharp report. The fractured ends are carefully fitted together and measured as before. The comparison of these new measurements with those previously taken gives the percentages of reduction of area and elongation. The ultimate T. S. and elastic limit are calculated from original sections. Elongation varies widely with the location of the fractured section. The nearer the grip the less the elongation; the nearer the center of the specimen the greater.

CHARACTERISTICS OF FRACTURES.—An excellent criterion of the steel is afforded by the form and appearance of the fractured section. Cup-shaped fractures with fine crystallization and uniform gray color, technically termed silky, indicate homogeneous well-rolled metal. Sliding fractures occur frequently but are not so favorable. Irregular jagged fractures are to be distrusted. Mottled, parti-colored streaks, bright spots, dark patches, and coarse crystallization evidence poor metal, and should arouse suspicion however good the tensility and ductility. Blotches and parti-colors point to over-heating; patches and streaks denote segregation and cold rolling; coarse granulation implies insufficient work, high phosphorus, or burned metal. Each impurity in the ore, each atom of mechanical work, each thermal unit, has left its mark writ ineffaceably in the resultant steel, and he who knows may read.

QUENCHING AND COLD BENDING TESTS.—The quenching specimen, raised to a dark cherry-red in a fire free from smoke, is plunged into water at a temperature of 82° F., then is bent cold around a curve three-halves the thickness of the specimen. Properly performed, the quenching test will detect cold rolling, brittleness, and segregation, due to phosphorus. A well rolled plate of good material should close upon itself without cracks. This test is known to the trade as the temper test.

Cold bending requires that the specimen, as it comes from the finished material, should close upon itself without cracks or flaws. Very few pieces fail. Thin pieces readily fold twice without cracking. Good steel, well rolled, will close readily under a trip hammer when under $\frac{3}{4}''$ thick. Heavier specimens should be placed under a hydraulic press, whose slow, regular pressure permits the cold flow of metal. Wide specimens do not bend readily. Rivets are required to be both cold flattened and hot flattened under hammer. Additionally they are bent into a hook.

ADDITIONAL TESTS FOR SHAPES.—The additional tests for shapes are cold-opening, cold-closing, and shocking or percussive. For beams the opening and closing is a single operation. Under a hydraulic press the angle is bent cold until its inner edge touches the web. This test is especially severe on large sections. Much trouble was experienced in testing 9″ bulb battery beams for the U. S. S. "Charleston." Most of the original beams broke short off in the web,

close to the fillet. These beams were rolled from unconditioned Bessemer steel, and the fractures disclosed large, weak, fiery crystals. At present all beams are conditioned in that arch enemy, phosphorus, and the metal must be open hearth. Angles must also open and close without fracture. Few fail in opening, the closing test being the more severe. The present drop or shocking test affords an excellent method of judging of the brittleness.

A 5" x 3" x 9' reverse bar of open hearth steel for the armored battle ship "Maine," now building at New York, endured thirty-three blows from a 640-pound weight dropped 5 feet. The bar inverted after each blow was bent over 90°, and showed fatigue after the twenty-fifth blow. When fracture occurred, the steel tore, not split, half across the narrower angle. At this time the bar had lost all semblance to its original shape, being twisted and flattened. Similar tests made with cold punched bars showed that the fractures rarely extended into the holes, though often grazing them. A better material for ship building can hardly be asked. Hulls framed of such metal will endure any amount of battering, bumping, and ramming before breaking.

BOILER PLATES AND STAYS.—All boiler plates must be of open hearth steel conditioned to .035 of 1 per cent of phosphorus, and .040 of 1 per cent of sulphur. Each plate is tested independently and stands or falls upon its own record. Hull plates are tested by heats. Test specimens are cut both longitudinally and transversely, the transverse specimens showing higher tensile and lower elongation. Owing to the greater size of the ingots, due to large and heavy plates, there is more difficulty in proper heating, the outside frequently bleeding before the core is sufficiently hot. This causes more pits and laminations. Thus, the shell plates for the boilers of Cruiser No. 5 were $\frac{35}{32}$" thick, and weighed finished 5,000 lbs. each. Ingots for such plates would weigh from 8,000 to 10,000 lbs. The economy of fuel in high pressure boilers has already forced us a long way in increase of strength of material. Our new cruisers, with boilers 15' 9" diameter, working under pressures of 160 lbs., show how far we have progressed. The introduction of high tensile, high carbon wide shell plates is not entirely devoid of danger. High carbon means less dependence. Plates over 70 inches wide develop defects which narrower plates escape. We shall be told that wide plates are preferable to

many rivetted seams. We concede that these seams are but 70 per cent of the plate strength, but no man knows not how much but how little strength there remains in a wide plate cold rolled. A working pressure of 160 lbs. gives 6 tons to the square inch upon the plates, and about $8\frac{1}{2}$ tons between the rivet holes. As the elastic limit is but 16 tons, it would seem that we had about reached the limit that prudence dictates. The advantages already gained by the use of such a fine material as mild steel are evident.

Corrugated flues found their way into favor in 1878. It is really the adoption of light corrugated steel furnaces that has made possible the present high pressures and temperatures. There has been little trouble in getting a sufficiently strong shell plate even of iron, but with present temperatures in furnaces iron is too apt to blister. Without the increased strength added by corrugation, even steel plates would have been too thick to withstand the heat. As it is, even now, we cannot carry the pressure much above 200 lbs. without coming uncomfortably close to the dreaded blue heat in the furnace plates.

The electric welding people anticipate being able to weld boiler plates, which will be a second saving of weight by doing away with butt straps and rivets. One English firm produces circular weldless boiler plates 48″ width by 16′ diameter. The British Lloyds reduce the scantlings one-third for these boilers. For equal strength the saving in weight by steel boilers over iron is as 5 to 6. The greatest success to be attained by electric welding will be the welding of tubes to tube sheets. Not only would this be of the greatest service to the type now in use, but it would render practicable many forms of tubulous boilers, well designed for efficiency of heating surfaces and circulation, that fail on account of leaky tubes and complicated bracing.

The factor of safety in boilers has fallen steadily with the rise in pressures. This decrease dictated by necessity is warranted, in part at least, by improved material and superior methods of assembling. From a standard of nearly eight this factor has fallen to four. Efforts are now being made to test boilers to 90 lbs. above working pressures, and design the boiler for this pressure with a safety factor of about two and one-fourth.

In the navy we count the average life of a steel boiler at twelve years, which equals iron. In the merchant service the period would be extended to fifteen years. The cause of this difference is well

known. Our best boiler steel exceeds the best boiler iron in strength about 18 per cent.

ENGINES.—The use of steel in engines is as old as its use in boilers. We find it in the shafting of the Dover mail packets in 1857. These were of puddled steel. The failures of many Krupp shafts (T. S. 80,000 lbs., elongation in 8 in. 14 per cent) in 1863 greatly retarded further advance. In 1880, however, mild steel (T. S. 50,000 lbs., elongation 20 per cent) was introduced. At present we use a T. S. of 60,000 lbs., elongation in 2 in. 28 per cent, and consider 70,000 lbs. as the safe upper limit. All steel for forgings must be made by the open-hearth process, and must not show more than .06 of 1 per cent phosphorus, nor more than .04 of 1 per cent sulphur. All forgings must be annealed and free from cracks, blow holes, hard spots, and foreign substances. The cost of solid forged shafts is very great, as it requires a 42-ton ingot to complete a 17-ton shaft. The Bethlehem Co. now make shafts up to 30 in. diameter, weighing 40 tons each. The saving in weight over iron is about 36 per cent. At present steel is generally used for shafting, piston and connecting rods, valve and reversing gear, various arms, rods, etc.

Cast steel is preferred for engine frames and bed plates, pistons, cylinder and valve chests, bonnets, cylinder liners, etc. Wherever it replaces iron a saving of at least 25 per cent can be reckoned upon.

For tension and ability to resist shock cast steel is one-third stronger than wrought iron; forged steel three times stronger. Similar relative superiority exists in transverse and torsional strength. The steel castings for the gun-boat "Petrel" gave T. S. 72,196 lbs., elongation in 2 in. 32.5 per cent, reduction of area 35 per cent. Specimens bent cold 116° without fracture, and this is cast, not wrought, metal. The advance in ductility in castings has been very rapid. The substitution of cast steel of a ductility superior to old forgings for moving forged portions is already begun.

ANCHORS AND CHAINS.—The anchors for the navy have cast-steel crowns and flukes with forged iron shanks. The requirements for the steel are, after annealing: T. S. 60,000 lbs.; elongation in 8 in. 15 per cent; phosphorus .06 of one per cent. The weight is practically the same as iron, as lessening an anchor's weight lessens efficiency. The gain in strength exceeds 35 per cent.

We have not as yet secured steel chains for the navy, but the

great superiority of mild steel over iron in ultimate strength, elastic limit, and elongation reinforced by electric welding must cause its speedy adoption. Cast-steel chains have been successfully made in England and France, and are sanctioned by the British Lloyds and French Bureau Veritas. We have none of domestic manufacture.

STEEL RIGGING AND ROPES.— For standing rigging, galvanized steel wire is used. The specifications require T. S. 160,000 lbs.; elongation in 10 inches 1.5 per cent; elastic limit 80,000 lbs. Additional vibratory tests are prescribed as follows: angle of vibration 40°; number of vibrations 1,300.

For running rigging and ropes annealed galvanized wire is preferred. Requirements: T. S. 70,000 lbs.; elongation 10 per cent, elastic limit 38,000 lbs.; angle of vibration 40°; number of vibrations 500. Steel is used for military masts and torpedo booms. The requirements are the same as hull steels.

STEEL FOR GUNS.—In 1884 the batteries of U. S. men-of-war were composed of Dahlgren and Rodman muzzle-loading, smooth-bore cast-iron guns of 9 in., 11 in., and 15 in. calibers; 8 in. muzzle-loading rifles, converted from cast-iron smooth bore 11 in. by the insertion of a wrought-iron tube; of cast-iron Parrot rifles with a reinforce hoop of wrought iron shrunk on; and of 60 lb. breech-loading rifles converted from Parrots. No nation upon this globe floated such antiquated, obsolete guns as we. The best of the guns had a penetration of about ten inches of wrought iron at short range, and a total energy of less than 2,500 foot tons. Today we have in service, or approaching completion, high powered breech-loading rifles of 4, 5, 6, 8, 10, and 12 inch calibers. The 6 inch, a light gun weighing only five and one-half tons, has a total energy of over 2,700 foot tons, with twelve inches penetration of wrought iron, whilst the 12 inch, weighing 45 tons, develops an energy of 26,000 tons, and has a penetration of 27 inches of wrought iron.

The first steel gun made for the navy was of 6-inch caliber. The tube was of domestic steel, but the jacket was English. The second gun of the same caliber, now on board the "Dolphin," is wholly of domestic steel. The original requirements were: T. S. 70,000 lbs.; elastic limit 26,000 lbs.; elongation 20 per cent; reduction 35 per cent. We now require from the oil-tempered material

	T. S. pounds.	El. L. pounds.	Elong. 2 inches.
Tubes, . . .	70,000 to 80,000	33,000 to 38,000	12 to 22 per cent.
Jackets, . .	74,000 to 85,000	34,000 to 40,000	12 to 20 "
Hoops, . .	90,000 to 100,000	45,000 to 50,000	12 to 18 "
Trun. Bands,	80,000 to 90,000	36,000 to 40,000	6 to 12 "

Test specimens are cut transversely as well as longitudinally. "Forgings must be made of open-hearth steel of domestic manufacture, from the best quality of raw material, uniform in quality throughout the mass of each forging, and throughout the whole order for forgings of the same caliber, and free from slag, seams, cracks, cavities, flaws, blow-holes, unsoundness, foreign substances, and all other defects affecting their resistance and value."

The trunnion band is an unhammered steel casting, rough bored and turned, annealed, oil-tempered, and again annealed. It is screwed on and held by a set screw. The elevating band of wrought iron is shrunk on and keyed. All other parts of the gun proper are forged steel. The steel maker is required to discard 30 per cent of the top and 5 per cent of the bottom of each ingot. Tubes, jackets, and hoops are forged from solid ingots and afterward bored. For tubes we require the bored ingot to be reduced 50 per cent in thickness, and for plugs and mushrooms the same. Jackets must be reduced 33 per cent, and hoops at least 30 per cent. All forgings, after forging is completed, must be annealed, oil-tempered, and re-annealed. Tubes, jackets, and hoops are forged closely to dimensions and afterward bored.

Without entering into the details of gun construction it will suffice to state that over the tube is shrunk a heavy jacket, about one-third the length of the tube. From this jacket to the muzzle are shrunk a series of lighter hoops. Outside the jacket are again shrunk a row of heavy hoops constituting a second reinforce over the powder chamber and the seat of the projectile. The breech-loading apparatus, of the interrupted screw type, locks into the rear end of the jacket.

By the method of shrinkage, the bore in all the new guns is compressed nearly to its elastic limit, *i. e.*, about 35,000 lbs. The actual diametrical compression rising from 0.005" at the muzzle to 0.016" at the rear end of tube.

All calibers have about the same strength, though the larger have a *greater factor of safety* than the smaller ones. Slower burn-

ing powder is used in large calibers. Were it not for the erosion of the bore by the gasses of explosion the life of these guns would be indefinitely great. Raising steel to a strain closely approximating its elastic limit raises the limit itself, and if this could go on, the strength of the gun would be infinitely great.

The erosion mentioned causes unevenness in the bore, and this in turn affects accuracy. A new steel liner corrects this evil. Five hundred rounds would probably injure a large gun so as to necessitate relining. One of the "Dolphin's" 6-inch guns has been fired over 300 rounds with little apparent wear. Abroad, 10 and 12-inch calibers have been fired from 600 to 800 rounds without relining. Target charges are reduced, and the velocity falls to 1,700 f. s. in place of 2,100 f. s. The maximum pressure now allowed in the bore is 15 tons, say 32,000 lbs. per square inch, but we anticipate pressures as high as 17 tons in the near future. The muzzle pressure is about 4 tons.

The cost of these guns, roughly speaking, is about 50 cents per pound when ready for service. The price per pound falls with increase of weight.

Although a 16-inch gun to weigh 125 tons has been authorized by Congress and designed, it is more than doubtful whether it will ever be constructed. Possibly a 13-inch caliber, weighing about 60 tons, may be substituted. The recent failures of English 100-ton guns has cast discredit upon monster ordnance, and as a 13-inch gun can penetrate 28 inches of wrought iron, there is little to gain in exceeding this size. Ranges of modern high-powered ordnances are above one mile for each inch of caliber at extreme elevations. The length of the gun is a more important factor than the size in this respect.

The largest guns in the world were made by Krupp for the Italian government. Weight, 119 tons; caliber, 15.7″; length, 46 ft.; weight of projectile, 2,028 lbs.; charge, 727 lbs., though 860 lbs. has been fired; velocity at muzzle, 1,800 f. s.; energy, 46,000 foot tons; penetration, 30″.

STEEL CAST GUNS.—Under act of Congress, two 6-inch steel cast guns, weighing about 5½ tons each, have been offered for statutory trials. The first trial was of Bessemer steel. About 20,000 lbs. of metal were poured, the gun being cast solid. After rough boring, the gun was first annealed, then steam-tempered and again annealed. The

rifling was done at the Washington navy yard, and the gun taken to Annapolis for trial. The conditions imposed ten rounds in quick succession, and the charge sufficient to ensure a muzzle velocity of 2,000 feet per second for a 100-pound projectile. A preliminary warning charge having been fired, the gun was loaded with forty-eight pounds of brown prismatic powder and projectile. The gun went to pieces abaft the trunnions, the bursted segments completely wrecking the heavy 12-inch timbers built over and around it. The breech mechanism was found intact. The pressure gauge indicated fourteen tons. As the usual energy of such a charge is fifteen tons, it is evident that the walls of the gun gave way before the gasses had been fully evolved. The physical characteristics of the metal were: —

	T. S. lbs.	El. L. lbs.	Elong. in 2 in.
Breech long., . . .	89,686	51,693	9.75 per cent.
" trans., . .	73,236	57,290	0.60 "
Muzzle long., . .	81,185	40,461	18.00 "
" trans., . .	79,174	41,500	16.50 "

The wide variations and almost total absence of elongation in the transverse breech specimen are full of significance. As the gun was cast breech up of indifferent metal, with an utterly insufficient sinking head, the reason for the unsatisfactory breech specimen appears. A chemical analysis of the borings constituted as good an instance of lack of homogeneity and marked segregation as exists. The failure of this gun shows that poor steel, badly treated, cast without safeguards, tempered by a process as unusual to good metal as to the maker, will not bear strains that call upon the best steels for all their elasticity and strength.

The second gun was of open-hearth steel, of good metal, cast by a company of acknowledged merit, with every precaution their large experience could suggest. This gun withstood the ten rounds without apparent injury, but the star gauge developed serious enlargement of the bore. The elastic limit had been exceeded, and the gun ruined for ordnance purposes. In Sweden, however, guns up to 5.2-inch caliber have been successfully cast and successfully fired. It is useless to go over the arguments of built-up versus steel cast guns. Certainly, the advocates of the built-up guns have the best of the facts. I hazard little, however, in believing that the question may assume a different

aspect with the improvement in casting. The present system has in its favor the practical impossibility of incorporating bad steel in any gun. The navy is fully committed to the built-up system, and the guns we are now building are in all respects the equals, and in many the superiors, of those of any other nation.

STEEL GUN CARRIAGES.—The pneumatic gun carriage has every part of steel. The slides are horizontal, and the downward strain is taken entirely from the deck (excepting the component due to impact). The strain from the recoil is taken up in line with the horizontal side cheeks, by means of recoil cylinders supplied with compressed air from a reservoir and air compressor. The pistons are solid, without packing, and less in diameter than the cylinders. This permits a displacement of air in recoiling, giving nearly an equilibrium of pressures at the termination of the recoil. The difference in areas of piston head and back is sufficient to bring the gun back into battery. The initial cylinder pressures are from 250 to 400 lbs. per square inch. The mean pressure during recoil is slightly over 700 lbs., and the maximum pressure about 1,900 lbs. The usual length of recoil is less than 24 inches, but the length can be reduced. The carriage is trained and the gun elevated by one man standing at the rear. The extreme elevation is 18°, depression, 5°. The gun is also loaded by pneumatic power. This carriage has been successfully tried, and one of our monitors is now being equipped with them. The one serious difficulty yet encountered with it is the leakage from the recoil cylinders. Though not accepted as a navy standard carriage, it has been tested and adopted for special use.

In thus reviewing the steps by which steel has supplanted iron for naval purposes, I have deemed it essential to dwell at length upon the rigid inspection and tests exacted prior to acceptance of material. Naval inspection has served to establish standards where none previously existed, and its influence upon the character of steels throughout the whole country has been marked and salutary. It is not an exaggeration to add that the navy demand, though not exceeding one per cent of the total product, has served to raise the character of steel in every art. Beyond this, the encouragement afforded by government orders, has rendered possible the installation of special plants requiring enormous capital. Once established, the entire country reaps the benefit of the improved manufacture. The possession of efficient men-

of-war, armed with powerful guns, capable of sustaining the dignity of a great power, is the least of the advantages reaped by the nation. The direct service to every mechanical trade has already returned to the people the prime cost of the new navy.

MEETING 401.

The Application of Storage Batteries to Street Car Propulsion.

BY COL. E. H. HEWINS.

The 401st meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, March 27th, at 8 P. M., President Walker in the chair.

After the reading of the records of the previous meeting, and the election of new members, the President introduced Col. E. H. Hewins, general manager of the Union Electric Car Company, who read a paper on "The Application of Storage Batteries to Street Car Propulsion."

COL. HEWINS said: The question of street transportation is one that more nearly concerns every individual in the community than almost any other, and its solution is one that has occupied prominently the attention of engineers in all ages. The modern horse car is the result of the accumulated experience of ages, but now the demand is for something still better. In this service is invested immense capital, it furnishes employment to thousands, it serves millions, and comes into most direct contact with the masses.

Here is the opportunity, and perhaps here more than anywhere else is to be wrought out the old problem of the proper relationship between capital and labor, and state or corporate ownership. The signs of the times already indicate this latter to such an extent that all should take note of passing events, and the Nationalist says the community must address itself to the solution of this momentous question.

In many cities the streets have become so encumbered with horse cars that it is absolutely necessary to find some improved means of meeting the rapidly increasing demand, and here as in New York it would seem that an elevated road must soon come, that no improvement now contemplated or dreamed of in surface facilities could possibly keep pace with what sometimes seems to me an insatiable and growing desire to ride,— so great is the increase wherever the opportunity is furnished.

It has always seemed to me that the matter of street traffic was similar to building uses. When you settle a new country, you first build log huts with one or more rooms on the ground. As the country fills up, and houses get nearer together, you put first attics and then more stories to the buildings,— the more people and business the higher the structures. Now the Government undertakes to supply the road or street facilities for communication; but, not as enterprising as individuals, provides but one story. Let me ask why should we not, in congested districts, have two-story streets as well as high buildings?

It is not my purpose to quote statistics or to recite history, but to give some explanation of one method by which it is hoped to improve our street car service, and to that end the application of storage batteries to street car propulsion ought to be both interesting and instructive. It is unnecessary to relate the desirability, for many reasons, of avoiding the net work of wires employed by the trolley system, nor the numerous advantages of having each car complete in itself, self-contained, and able to travel wherever there may be tracks without other special constructions or obstructions. These are all unquestioned by any of whatever belief or interest. It resolves itself into the one dispute as to whether the thing can be done

The experience of most of those who have tried it is pointed to as disastrous on the ground that storage batteries cannot endure, and it is said that when storage batteries have been so far improved that they can be depended upon to deliver the necessary power, then we may have the ideal motive power for street car service.

There is one peculiarity that is common both to the storage battery and the dynamo,— they may be likened to the thoroughbred, who will do all that is asked of him, though he die in the attempt. If used within his capacity, a most serviceable animal, but if thought-

lessly, carelessly, or ignorantly used, a very costly horse may be quickly and seriously injured. So far as I have been able to learn, with one exception, the employment of storage batteries for street car work has thus far required a drain greater by far than any maker ever claimed to be their ability to deliver. The result has been the prompt destruction of the battery.

It may be well to interject here some of the characteristics of storage batteries, though not with any purpose to undertake a thorough description of this peculiar agent. I gather from the different details of construction shown by different makers that in one respect they may be separated into two classes,—one constructed upon the theory that as much *surface* of plate as possible should be exposed to the solution, and the opposite that *mass* of active material is the desired object.

Your attention is directed to the several elements shown on the table, which illustrate these two extremes to a great degree, as well as other characteristics. In one you will observe that the plates are thin and placed near together with as many plates as possible, giving large surface in contact with the solution in which the plates are immersed; while the other is constructed of thick plates placed far apart, thus exposing comparatively small surface to the solution, but containing large mass and large surface between the active material and its carrying lead plates, which is claimed to be desirable. Again, we see a pile constructed upon quite a different principle. Its active material is not made in the form of a paste, paint, cement, or powder; but is melted and cast, so that it exposes more surface to the solution than either, and is claimed not to deposit or waste away in use.

I also understand that the nearer together the plates can be put without touching the better, provided they can be secure of parallelism. In two of the piles here shown is a marked peculiarity to which I would call your attention, *i. e.*, the one that is mechanically the most certain of remaining in position has double the space between its plates that is exhibited in its competitor.

However it may be obtained, whether by small space between the plates, by large amount of surface exposed to solution, by large mass of active material, or by large surface contact between active material and its carrying lead plates,—the desired objects to be secured are low internal resistance and capacity.

As throughout the realm of physical science there is no gain without compensation, so each of these various qualities is obtained only at the sacrifice of some other. (Later on I shall call your attention to a seeming contradiction of this theory where we "eat our cake and save it, too.") Just what relative proportion in these various respects will in the aggregate give the best results will probably never be agreed upon by the different competitors. The purchaser, whether competent or not, must decide for himself.

In the practical use of storage batteries it is desirable to charge and discharge at a low rate. If the rate be too high, the heat generated expands and warps the plates. The expansion, or rather the subsequent contraction, injures the contact between the active material and lead; the warping brings adjacent plates nearer together at places; both resulting in the generation of more heat,— one because of imperfect contact, and the other because of the greater flow of current at those places where warping has taken place; and so the work of disintegration goes on with increasing rapidity. If, however, the rate is confined within certain limits, it is found by experience that the batteries endure, except for the slow, gradual wasting away of active material in a powder form from the positive plates. This is not expensive in its renewal, but the effort now is to reduce the rate of this reduction.

The question then comes: How to do the service with less, or, what is the same in effect, how to economize the energy we have at command so as to keep within the capacity of the battery. It was conceived some four years ago by Mr. William L. Stevens, then and now electrician for the N. E. Weston Electric Light Company, that the gearing employed to transmit the power and to reduce the rotative speed from the motor armature to the car axle, exposed as they were to dust and not well lubricated, must be a very inefficient method of transmission, and his studies and experiments finally produced a train of gears which, instead of the exposed gearing in common use with counter-shaft passing through between the field coils, is nested concentrically around the axle, enclosed in a dust-tight case, and runs in a bath of oil. In addition, the strains in all but one place are equalized on opposite sides of the shafts, so that the minimum of friction and wear is secured. Careful measurements have shown that not less than one-half the electrical energy is consumed in the friction of the

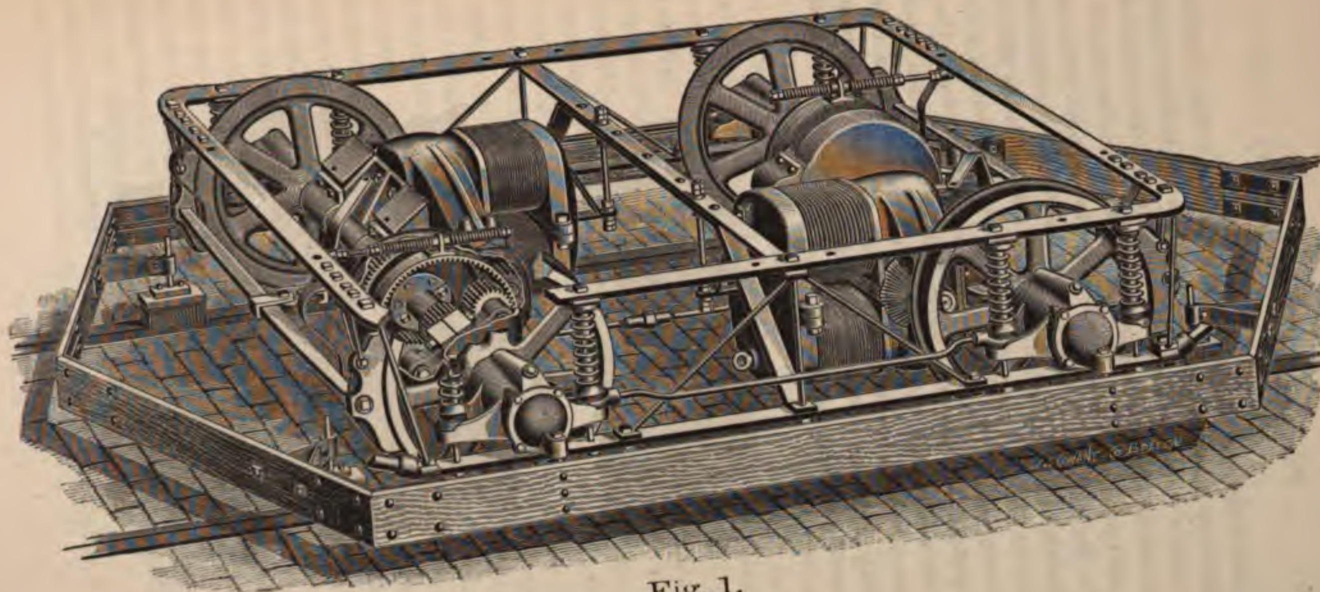


Fig. 1.

exposed gears and bearings in common use. This friction is made manifest by the wear, practical examples of which are exhibited upon the table. Here are four pinions from one of the prominent systems, worn out as you may see, one in less than one month, the average life said by the road officials to be about two months. In contradiction, here is the pinion from an armature shaft of the Stevens gearing that has run about 8000 miles, and you can see that it has lost practically none of its life. Thorough lubrication and cleanliness are the secrets of its endurance. You will also notice the difference in the faces of these pinions,—the one that shows little or no wear has but $2\frac{1}{2}''$ face, while the others have $4\frac{1}{4}''$ face. The one has not been required to transmit more than one-half the power of the others to accomplish the propelling of the car. Fig. 2 shows a pinion made of cast steel which was worn out in four months' use.

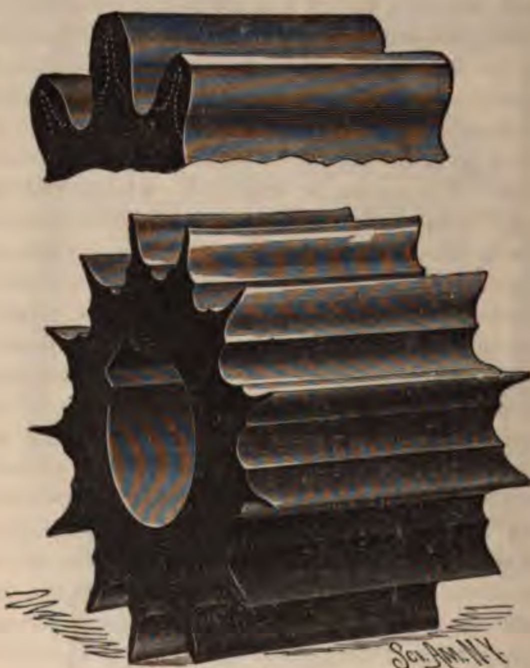


Fig. 2.

In addition to the saving of energy and repair is the fact that the truck rides much easier, not being rendered stiff by the gearing and counter-shaft,—quite a difference in the agreeable riding of the car, and also, what is more important, an absence of noise from the gears, which, when considerably worn in the systems with which you are familiar, is very excessive; so that conversation is difficult. No doubt many of you have noticed that when new cars or lines are started the noise is very much less than after being run a few months. This is very largely due to the wearing of the gears.

Another important feature of Mr. Stevens's invention is called the "recharging" device. This invention consists in rendering a series-wound machine, either a motor or dynamo, as the occasion may call for, without the necessity of human intelligence or action. The possibility of doing this without mechanically reversing the field connections, and the application for a patent, were denied, and it required quite an effort to convince the Patent Office that it was being done daily. It simply consists of a few cells of battery put into a shunt circuit with the field coils. The result without these supplementary cells is that when the car tends to run faster than the position of the switch handle indicates is desired, the counter e. m. f. becoming equal to that at the binding posts, no current flows, and consequently there is no magnetization of the field magnets; but with the elementary cells the field is kept charged in the right direction, and immediately the speed has increased beyond the desired rate, the machine driven by the car generates a current in the direction opposite to that which drives it as a motor, and the current so generated is returned to the batteries or to the line as the case may be,—for it is to be understood that this system is equally applicable to storage battery, to overhead or underground conductors, or to a combination of the two. For instance, there are places where overhead construction might be unobjectionable and even desirable, but on a continuation of the same route inadmissable. In such cases the car would habitually be started with current from the battery, and after having attained a proper speed be switched onto the trolley, and while so connected the battery would be charged. When the end of the trolley wire is reached, the car would be run over the balance of the route entirely with current from the battery until its return to the trolley wires.

Cars equipped with this system are habitually run down hill, and

restrained from going too fast and stopped by this recharging device, the hand-brake being used only when stopping on a grade, and to hold the car while standing. Thus it will be seen that the energy of the ordinary brake employed by other systems to hold the car from going faster than desired, or to stop the car, is by this system returned to the battery to be used over again, or to the line to reduce the amount of power generated in the power house. This is saving the cake that is also eaten. The amount of energy so returned to the batteries on the Beverly and Danvers street railway is determined by careful measurement to be about fourteen per cent of that taken out, and after reduction for efficiency of batteries, loss in conductors, etc., leaves about nine or ten per cent, as the increased mileage due to the charging back device. The motion of the car is by its use made much more agreeable, and its control more effective.

Had the car that recently ran into another on Warren Street been fitted with this simple recharging attachment, the collision would not have taken place, notwithstanding the fact that the trolley was off the wire.

The two curves shown in Figs. 3 and 4, taken on different electric railroads, showing in a graphic method the amount of horse-power necessary to propel electric cars, are interesting. The curve in Fig. 3 was made from data taken on a car on a level road, using the ordinary overhead single trolley system, with the motor armature geared to the wheels by the ordinary two sets of gears open to the dust gathered from the road. The curve in Fig. 4 was formed from data taken on the Beverly and Danvers Railroad, which is very hilly, on a car equipped with this system. As will be seen from the first curve, it took about twelve horse-power to start the car at first, the gear being new ; and at a certain part of the road consumed 20.1 horse-power. The next start took 21.4 horse-power, while the third start took 33.5 horse-power, presumably owing to the gear getting dirty, making an average throughout of 9.8 horse-power over the whole run. In the lower curve on the Beverly road the car was started with from 5 to 10 horse-power, and running at the same speed as in the former test the highest horse-power consumed was 16.1, while, where the curve passes below the horizontal or "no-current" line, considerable saving was effected by charging back, as much as 19.8 in one case being returned to the battery. The average horse-power in this case

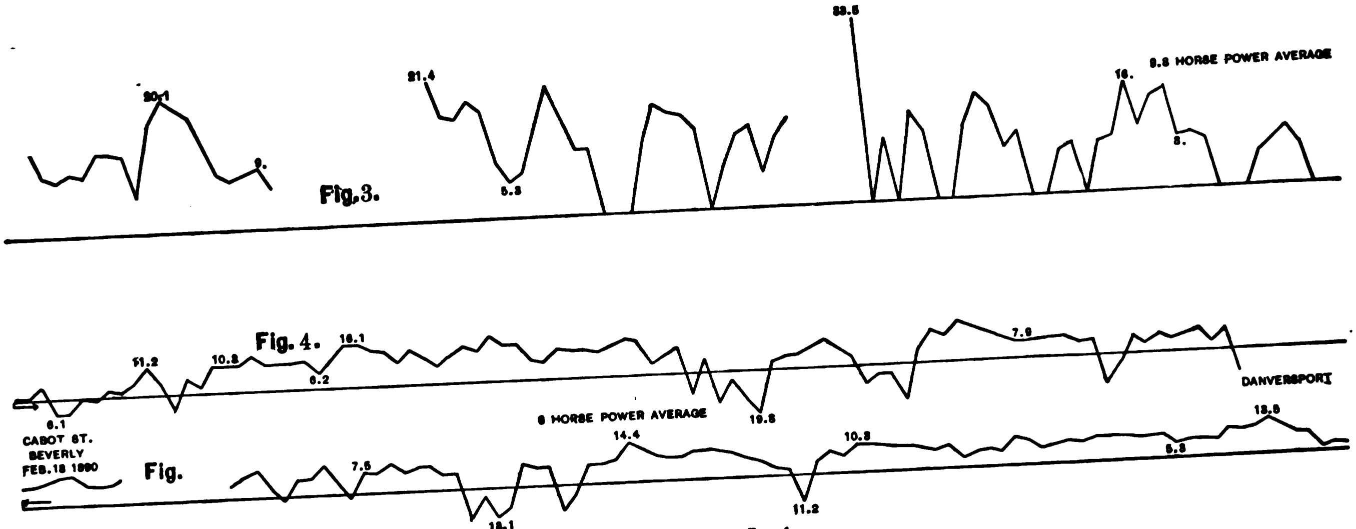


Fig. 3.
20.1
9.
21.4
5.3
33.5
18.
8.
9.8 HORSE POWER AVERAGE
Fig. 4.
11.2
6.1
10.8
6.2
16.1
19.8
7.9
DANVERSPORT
CABOT ST.
BEVERLY
FEB. 18 1890
Fig.
7.5
18.1
6 HORSE POWER AVERAGE
14.4
11.2
10.3
5.3
13.5

Figs. 3 and 4.

is put down at 6, but as a matter of fact it is about 5.54. The saving over the whole line by charging back is about fourteen per cent, as stated above. The saving in such a case is not at first easily seen, but we think a careful study of the above curves will prove that there is yet much to be improved in the ordinary method of running electric cars, and they will serve as an explanation of the acknowledged and unnecessarily high power which today is regularly being consumed on electric railroads.

The methods that I have tried to describe to you perhaps seem too simple and too easy of accomplishment to be sufficiently effective, but a serious attempt to do it I think will convince the most sceptical that it is not so easy as one would be inclined off-hand to assert, and it is a fact that a sufficient amount of power is saved to enable the storage battery in its present stage of development to do the work. This is the important consideration, and what it has been sought to accomplish. I do not doubt that the frequent recharging of the batteries while in service increases their endurance, and no doubt the constant agitation of the solution enables them to withstand heavier drains than would be the case with stationary work.

This system was applied last summer as the motive power to a transfer table at the car shops of the Fitchburg Railroad at East Fitchburg. The current is taken from the same dynamo that furnishes light for the shops, and is carried to and from the motor by two wires and trolleys.

MEETING 402.

Experiments with Alternating Currents.

BY PROF. ELIHU THOMSON.

The 402nd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 10th, at 8 P.M., Prof. C. R. Cross in the chair.

After the reading of the records of the previous meeting, the chairman introduced Prof. Elihu Thomson, of Lynn, who read a paper on "Experiments with Alternating Currents."

PROF. THOMSON said: The study of alternating currents and the effects of such currents in producing fields of magnetic influence has been greatly stimulated by the industrial development taking place with alternating currents in electric lighting. In particular, the phenomena occurring as a result of induction and self-induction have opened to us very many interesting fields for study and investigation. The consideration of the action of displacement of phase due to induction or self-induction, as the result of a retardation or lag brought about by such induction or self-induction, has been particularly interesting and fruitful. Much light has been thrown upon the more obscure actions occurring in ordinary electrical apparatus using continuous currents by the analogous but more pronounced effects obtained with alternating currents. The subject of losses due to magnetic friction or hysteresis has been and is receiving careful study in the hands of some of the ablest electricians. The revival of the almost forgotten idea that the static spark or Leyden jar discharge is an alternating discharge at a very high rate or speed of reversals has not only assisted in our general understanding of electrical actions, but has borne fruit, it may be truly said, in the experiments proving that light and radiation are phases of electrical action,—not, as I have seen seriously discussed that light and electricity are one and the same thing, but that light and radiant heat are related to the science of electrical undulations or vibrations. It becomes simply, then, a widening of the electrical field to cover light and radiation, not a question of identity in all respects.

In the same way I anticipate eventually that we may learn by experimental research, coupled with theoretical considerations, that conduction of electrical current is not different from electrolysis in essence, except that the interchange of atoms in molecules of the conductor replaces that occurring in the electrolyte, and where the conductor is a solid a restriction of the decomposing and reforming molecules to definite positions occurs, while in the electrolyte the newly formed molecules are freer to move, and may therefore take new positions.

I anticipate, further, that we may learn that the warming of a body absorbing light or radiant energy is a result of almost infinitesimal closed electric circuits, just as the warming of a copper plate exposed to magnetic waves is due to electric currents on a larger scale. It may be possible also that we may learn to regard atomic move-

ments, or transfers of atoms from molecules to other molecules in chemical actions, as brought about by electrical strains; perhaps to find that the dispersion of light by refracting media is in reality closely related to such strains affecting the atoms or atomic structure, as distinguished from the molecular structure; or it is a kind of atomic interference phenomenon. Already we are compelled to admit that the atomic structure of heated gases is such as to enable the atoms to give out definitely repeated electric strains, that is, definite wave lengths of light or color,— that the atoms are, as it were, like tuning forks of definite pitch, which, instead of setting up sound waves, can give forth electric waves.

It is not impossible that the science of chemistry itself may be adjudged to be a department of electricity. Whether gravitation and other molecular forces and properties will eventually be found to be so closely related to electrical actions is difficult to say. Perhaps we may be able to make the broader statement that the properties of the universal ether are electrical, and all the phenomena of the physical universe are closely related to, or exemplify the properties of, the ether.

I have extended this opening statement to some length, chiefly because I did not wish to miss the opportunity of furnishing, if possible, some food for thought, and because what we are to deal with in our experiments here are some instances of phenomena which depend directly on the ether motions, and not on the air, that is, they depend upon waves in the ether differing from those of light and radiation by being of extremely slow rate comparatively; but a very few hundred a second instead of millions of millions.

If we pass an alternating current through a coil of wire surrounding an iron wire core, or even if such core be absent, we will obtain an alternating magnetic field around the coil and core. The polarity or direction of the magnetic lines in such field is reversing a number of times per second, equal to the number of changes in the direction of the current in the coil. Now, if we immerse in such field in the proper way a closed coil of wire, a band of conducting metal, a plate of metal, or in fact any substance which conducts electricity, it will be the seat of currents of alternating direction corresponding to the inducing currents in the coil. The coil, band, or plate becomes a secondary circuit for the inducing coil. The ether waves or magnetic waves produce

waves of current in the conductor. There is, however, a strong repulsive effort exerted upon the closed coil, band, etc., when it is of such size and material as to have the currents induced subject to great self-induction. If the currents induced lag or are retarded, they become opposite in direction to those which produce them, instead of alternately opposite, and in the same direction. The currents induced tend to maintain a magnetic field of opposite direction of polarity to that of the inducing currents or field at any instant. If the closed coil or secondary band exerts by the currents induced in it a controlling effect upon the magnetic field, such that the normal directions of the magnetic lines set up around the inducing coil are greatly distorted, the repulsive effect is strongly produced, and can forcibly thrust the ring or band away from the coil, or it may balance the ring for a moment in free air (Fig. 1). Could we obtain a condition of stable

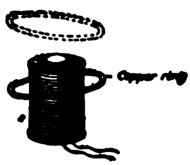


FIG. 1.

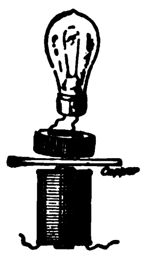


FIG. 2.

FIG. 3.

equilibrium in this case the ring would remain suspended, but the condition is one of unstable equilibrium, and the ring or band can only float securely above the coil when stayed at one side by horizontal strings.

Plates and discs of copper are likewise repelled or sustained. When one ring of copper is held in suspension above the coil or pole by alternating currents, another ring may be added and is supported closely parallel to the first ring, in virtue of the agreement of direction of the induced currents in both rings, which causes attraction, or makes them act as one ring. Too heavy a mass of copper, such as a heavy copper plate, will, however, cut off or so far distort or reflect the magnetic lines as to nullify their effects on a ring placed above the plate. This is exemplified very easily by substituting for the ring a

coil of insulated wire, whose terminals are carried to an incandescent lamp (Fig. 2). The lamp is lighted when the lamp-coil is held near the inducing coil or pole, and extinguished when the heavy induction shield or plate of copper is inserted between them. Hence, to cut off induction from reaching an object we may enclose it in a heavy copper box or shell, in about the same way as we cut off or shield an object from magnetism by enclosing it in a heavy iron box.

The lamp experiment just described suggests another, in which the lamp and the coil, for giving current to it, are floated, or rather immersed, in a vessel of water as in a jar, and then placed over the alternating pole (Fig. 3). Not only does the lamp light in the water, but the lamp and coil are lifted or supported from sinking, and at a depth depending on the current in the inducing coil, or the strength of the alternating field which it engenders. The lamp is self-regulating for variations in the force of the prime source of current. By counterpoising the lamp feeding-coil on a lever (Fig. 4), the brilliancy of the

FIG. 4.

FIG. 5.

lamp may in like manner be set by suitably weighting the lever. Or if several lamps in series be used, connected flexibly to a coil in the magnetic field of another coil, and either the primary or the secondary coil be balanced so as to tend towards the other with a definite force, the regulation of brilliancy is preserved not only during changes in the force of the primary current, but also during changes in the number of lamps in the series lighted by the coil. In other words, we are able to secure a complete regulation for all conditions. The device is an alternating current transformer, yielding a definite current strength for the operation of arc lamps, incandescent lamps, or other devices, either singly or in series of two or more. The lamps are

provided with the usual shunting switches. I have found also that the regulation may be obtained by governing in a similar manner the reaction or self-induction of the primary itself, or the primary current may be caused to traverse a series of lamps and a reactive coil, and the secondary coil or band be simply a partially balanced closed circuit, movable automatically to change the self-induction of the reactive coil, of which it is the secondary. It will be seen, then, that the repulsive action can be used practically in regulation of alternating current. Very good and effective practical measuring instruments, as well as alternating motors, have been based on the same principles of obtaining movement from such currents. Our time does not here permit a description of these. The regulating mechanism of arc lamps for alternating currents can equally well embody the repulsive devices of the closed band or circuit, and a coil in circuit with or in shunt to the arc.

We have shown the experiment of causing two rings to be attracted and held together while subjected to the alternating field. If we substitute for one of them a disc of copper (Fig. 5) pivoted so as to rotate easily, or a disc of iron likewise pivoted, we can, on variously placing the closed ring and disc in the field, obtain brisk rotation of the disc. A plate of copper or brass may be substituted for the ring, and, in fact, any closed conducting plate or piece of metal may be used. The action is due to the formation of parallel currents, or harmonizing and attracting fields, where two copper pieces are used, and to retention of magnetism or hysteresis where one of them is of iron.

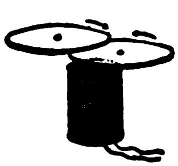


FIG. 6.

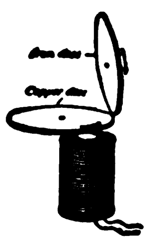


FIG. 7.

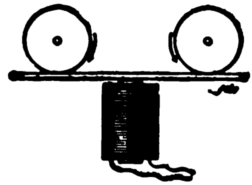


FIG. 8.

I would say here that Mr. M. J. Wightman and myself have carried on these experiments to a considerable extent, and amplified their effects in many ways, constructing motors, regulators, etc. based

thereon, and that they are capable of very much extension and modification. Some experiments of a novel character were shown last year at the Paris Exposition, and were based on the principles just touched upon. I have since that time extended the list, and now it includes quite a large number of curious devices.

In the disc experiments shown we used one disc and a shading plate or circuit, held stationary. By employing two discs of copper, (Fig. 6) or of copper and iron(Fig. 7), it will be seen that both may revolve, as one serves to modify the field for the other in each case. The positions of the discs relatively to the field are found capable of being considerably varied, and the rotative actions are readily made to take place in one or other direction. These variations are easily found by trial.

The discs of iron or copper may also be set rotating by a core wound with a coil conveying alternating impulses, and surrounded by coils or circuits which can be closed at will. An unsymmetrical placing of the disc, and an unsymmetrical position for the closed circuit, with reference to the middle of the length of the core, is conducive to this effect.

A curious variation of the rotating disc effects is obtained with pieces or bars of hard steel or iron, which resist reversal of magnetism. Placing a bar of steel, such as a file, upon the alternating pole, and holding the discs near the file (Fig. 8), is attended with rotation of the discs in a direction indicating a magnetic flow, or shifting set of lines or magnetic poles, proceeding along the file, from the vicinity of the alternating or inducing pole. Two or more discs may be easily set moving by the file laid across the pole. It will be noticed that while the copper discs operate only when their plane intersects, the direction of magnetism or magnetic lines leaving the pole, the iron discs operate in any position with respect thereto. This is easily explained by the fact that the copper discs move by virtue of *currents* set up in them by the changes in the magnetic field, and particularly in obedience to the shifting of the field, while the effect on the iron disc is almost purely magnetic, and not dependent on induced currents set up in it. The tendency to resist change of magnetic state accounts for the fact that the edge of the iron disc follows or tends to follow the development of polarity in the steel, which also resists magnetic change, and which therefore changes only progressively.

A curious experiment, combining the effects of closed circuits around cores and hysteresis, or resistance to magnetic change, is seen in the use of a cast-iron ring, on one part of which is wound a small coil of copper wire, closed on itself. When this is laid down so that the part of the ring near the closed coil rests on the alternating pole, and the pivoted iron disc is held near the center of the ring with its plane parallel to that of the cast-iron ring, there is noticed a rotation of the disc in a direction coinciding with propagation of magnetism around the ring, from the inducing pole along that side of the ring on which the closed coil is not wound, said coil appearing to shield or cut off its propagation in the other direction around the ring. The currents developed in the closed coil beat back the magnetic lines, while they remain free to move along the uncovered portion of the iron ring, and so drag the disc around also.

By taking advantage of the principles set down we may construct a simple motor, such as is here seen. A ring of laminated iron has a slot cut through at one part. The rest of the ring is wound with insulated wire through which an alternating current may be sent (Fig. 9). The sides of the slot or pole faces are partly shaded or

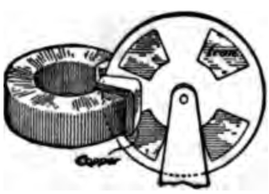


FIG. 9.

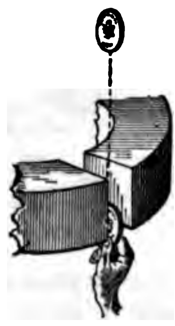


FIG. 10.

shielded by copper circuits affixed thereto on the upper part. The effect of this is to retard the development and change of polarities in the upper part of the opposed pole faces, and leave the action unhindered in the lower part.

Placing a copper disc mounted so as to be easily rotated, with one part of its edge in the slot, there results a vigorous rotation of the disc and the exertion of some torque. Removing the disc, we may

use the slot as a coin detector, for a silver coin is drawn in at the under side and projected upwards with vigor, while a base metal coin is not so affected, the superior conductivity of the silver for the current induced in it deciding the question (Fig. 10).

We may also cause rotation of a copper disc by holding it flatwise over the alternating pole and then placing a core of iron wires above the disc, but offset laterally from the axis of the alternating pole. The disc is immediately set into brisk rotation.

Copper balls or cylinders may be substituted for the discs. With a hollow copper ball resting on a shading plate (Fig. 11) placed over the alternating pole, curious rotatory effects are readily produced. Similar effects are produced when the balls are immersed in a vase of water over the pole (Fig. 12), the pole being partly covered by a copper or brass plate. The copper ball will even rotate on a horizontal axis, while resting against stops and on a copper shading plate, a movement showing considerable vigor of rotation which even overcomes the equatorial friction of the ball on the plate.

FIG. 11.

FIG. 12.

Here, as before, the cause of the action is the moving magnetic field in which the ball is immersed. The effects are those of retarded development of magnetism over the shading plate as compared with its development over the free part of the pole. This virtually amounts to a shifting of bundles of magnetic lines from the free part of the pole towards the shaded part at every alternation of current. These bundles may be said to brush the balls around. A copper cup may take the place of the ball in some of these experiments, or both ball and cup may be used together, while curious effects are obtainable from them.

A very good device for supplanting the copper and iron discs in some of the experiments is a combination of the two. A small shaft has some thin iron washers strung on it at the center, and around the edge of the iron discs is placed a copper ring or band, forming an overhanging rim like a pulley rim. The shaft is hung in a suitable frame to allow the device to be handled.

Placing a wedge-shaped piece of iron on the alternating pole, and with its edge upward (Fig. 13), we may bring the induction wheel, just described, near the edge, but to one side of it, and we will obtain brisk rotation of the wheel. On the other side of the edge the rotation is reversed. The action is due to the same cause as was found

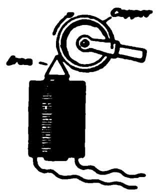


Fig. 13.

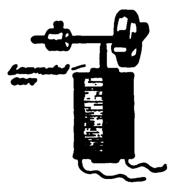


Fig. 14.

in the case of the steel file, though it is a curious modification, inasmuch as the appearance is as though something passed off the edge of the wedge, and blew the wheel around.

I have reserved for the last instance of these actions the case of a gyroscope of novel construction (Fig. 14). The wheel is like that just described, but it is mounted on pivots borne in a copper frame surrounding the induction wheel, which frame is in turn provided with a bar for pivoting and for a counter-balance weight. The instrument thus constituted is hung on a pivot placed in the center of the alternating magnet pole and held for a few moments, during which the wheel gets into rapid rotation. It is then capable of exhibiting all the well-known gyroscopic actions, which are a stumbling block to beginners in the study of physics, and than which nothing could be more simple and easy of comprehension when the true meaning of the actions is grasped. It is, indeed, curious to notice that in this electric gyroscope we have the electric rotations obtained, no doubt, from a direct absorption of ether energy or wave motion, without connection, electrical or mechanical, and that they are obtained altogether inde-

pendently of the gyroscopic rotations, which latter are not interfered with by the electric action.

The discussion of each case of movement produced in the experiments has necessarily been of the briefest kind, but it will be understood that there is material for minute study in any of the cases which have been shown. Many of the effects can be indefinitely modified. The examples given are intended to show in what respect the properties of an alternating field are such as distinguish it sharply from the ordinary unreversed field of a magnet, subject to the action of continuous current only. The experiments also bring out forcibly the effects of lag with alternating current waves. It is needless to say that the whole action and theory of lag or retarded phase has nothing parallel in continuous current work; that in dealing with alternating electric currents it is a most important action or effect, and that without a due regard for its importance many of the most interesting and instructive phenomena of alternating currents will fail of being correctly understood.

The paper was illustrated by numerous experiments and blackboard diagrams.

MEETING 403.

Central Electric Light Stations of London.

BY MR. FRANK M. GILLEY.

The 403rd meeting of the SOCIETY OF ARTS was held at the Institute on Thursday, April 25th, at 8 P. M., Hon. Jacob A. Dresser in the chair.

After the reading of the records and the transaction of some business the chairman introduced Mr. Frank M. Gilley, of Chelsea, who read a paper on "Central Electric Light Stations of London."

Mr. GILLEY said: Electric lighting in London does not have a long history, and if measured by what has already been finished would

not excite even passing notice. But it is the "what may be" successful systems that are now on trial there which the whole scientific world studies with interest. Activity in the promotion of companies to supply electric lights is of comparatively recent date, and it is only within the past year that the public has sought electric light stocks for conservative and legitimate investment.

Great Britain far surpasses us in legislation and red tape. In 1882 a few central stations were projected, and several cities and towns that were suffering as they thought under the burdens of private corporation gas monopolies were indirectly the cause of the passage of an act by Parliament, whereby electric light stations could be bought by municipalities after 21 years at the assessed valuation of the apparatus. Successful ventures could last 21 years; failures or partial failures would alone remain in the hands of private companies. The municipal control of gas works is common in England, and perhaps as successful as private enterprises but no more so. Private capital did not come forward very freely. Too much legislation had blocked the way, and, with the exception of a few experimental ventures, electric lighting was forgotten. In 1888 the time for the purchase of a plant by the local authorities was extended to 41 years, and some other concessions granted that made electric lighting possible, if not profitable.

To erect overhead wires a "license," *i. e.*, public consent, must be obtained, and of course where buildings are used for structures private consent as well; but as poles in the streets are rapidly excluded, the somewhat expensive and temporary system of housetop circuits did not find favor, except in a few instances, although all companies employing overhead wires exclusively were not subject to the selling out clause in the law of 1882. To obtain the right to open streets and lay underground mains a provisional order must be obtained, and this subjected the company to the danger of being bought at the end of 21 years by the local authorities.

After the change in the law in 1888 there was a boom; systems almost without number had been invented, and some perfected. To try each on a working scale many were ready to supply money, and by the end of last year 179 applications had been sent to the Board of Trade for provisional orders, one-third of which were from local authorities.

The business of manufacturing electric light apparatus is not under the control of a few large companies that use one system and work exclusively under all the patents of some one inventor. Ready made machinery in stock is no more to be found than ready made clothing, and even then the fit is not always to our taste. A variety of systems is made by almost every electrical engineering firm and no two installations look alike. Experimental work is often done in commercial stations, and thus the successful completion somewhat retarded. In striking contrast are the careful laboratory tests of new apparatus in this country, and the ready supply of the same when proved satisfactory.

In England the rights of consumers are carefully guarded, maximum price fixed, dividends in excess of eight per cent allowed if prices are proportionately lowered, and inspection of mains and meters provided for. Here generous concessions are made to companies, subsidies in the form of contracts for street lighting, and land grants in the very streets for poles. Some work in this country has been too hastily done, and the rights of the public have not been carefully preserved. In England current must be furnished at all times to every applicant by meter, and at a price not exceeding a fixed sum.

To a slight extent the low tension two or three wire "Edison system" is in use, but the contest is the most bitter between the storage battery and alternate current systems, the advantage in number of plants being with the latter. In granting "orders" to companies competition has been allowed by the Board of Trade and even favored, especially where both alternating and direct current systems could be supplied in one district, the fact being recognized that the alternate current motor is as yet not a commercial success.

The Metropolitan Electric Supply Company, one of the largest companies in London, has a large area allotted to it, and proposes to erect stations over the entire district of the 1000 volt transformer type with one exception, that of the Whitehall Place Station, which had been in operation some time before it was taken by the newly formed Metropolitan Company.

Whitehall is an imposing building for offices, and faces the Thames embankment and is close to the Grand, Metropole, and Victoria hotels. The building is not fully completed. The station is under the street or place at the rear, is entered through the building, and is connected to its chimney.

The plant consists of three Siemens shunt-wound dynamos, running 350 revolutions per minute, and connected direct to Willans triple-expansion engines, the exhaust steam being condensed in heating the building, passing through two heaters, one warming the water for heating the building, the second for the feed water. Pumps for water supply and elevator are in the engine room, where there is also a large tank for softening water. A fan operated by a steam engine exhausts air into the flue and reduces the temperature 15 degrees, which is 100° at the least calculation. In the Garrick Theatre there are 8 batteries of 44 cells each, charged with only 33 in series, when there are of course 10 sets. The Elwell-Parker type of cells is used here as well as at the station, and furnishes current while the engines are not working from 12.30 M. to 7 A. M. Two 8 sets of batteries, of which one-half are used every other day, can discharge, combined, 1700 amperes. Pilot wires are run to the station from the most distant points of the underground mains about one-half mile away. 100 volt lamps are used except in the theatre. The E. M. F. at the dynamos is 108 volts. Hand regulation is satisfactory with the engines. Three single-ended internally-fired marine boilers supply steam. The roof is formed of iron trusses supporting the paved street above. This station is worthy of notice as deserving a diploma for the hottest engine and dynamo room. It is a wonder that the storage batteries are not injured.

The reason assigned for the apparant want of success with storage batteries in this country, especially in New York and Philadelphia, is, according to English engineers, the excessive heat, but in this room they are operated in an atmosphere at a temperature not far from 100 degrees.

At Rathbone Place, Waterloo Bridge, Manchester Square, 1000 volt alternating stations were under construction. One at Sardinia Street, near Lincoln's Inn Fields, was completed last September. The interior is un-English. There are four 2500 light dynamos driven by compound engines made in this country, and are as much reason for congratulation as any of the notable victories by American scientists and manufacturers. At any rate, American electric lights have been so well liked that the original plant has been more than duplicated. The chimney of this as well as of the Rathbone Place station and many others is built with white enameled or glazed brick on the

outside. Such chimneys can cast shadows only when the bright sun is shining, a rare occurrence in London. At all other times so nearly of the same color and brightness of the sky do they appear that they would pass unnoticed. There is a curious law in London which may prevent the shutting off of any light from the sky by buildings erected near windows that have been in use for a long period.

The St. James and Pall Mall Company has a station off Duke Street, near St. James Square. This district was pointed out several years ago by Prof. George Forbes as the most favorable quarter for a low tension system. Offices, clubs, fashionable private residences, and stores demand a large and continuous supply of current. The district is less than a square mile, and the station not far from its center. The site, which was occupied by a stable, is a court yard, which is to be vaulted entirely by iron girders on which the yard is to rest. Two locomotive 400 horse-power boilers are in one portion of the cellar. The remainder of the cellar already excavated contains ten 200 horse-power Willans engines. The exhaust steam escapes by a separate flue built onto the 140-foot chimney. Overhead travelers facilitate the handling of engines and dynamos. These rest on concrete 8 feet thick, and there is a trench the whole depth of the concrete around the engine room to stop noise and vibration. The company was several times complained of soon after it began operations in April, 1889, but on investigation it was found that the engines were not running at the times stated in the complaint. Great care is used in every installation to give no grounds for complaint, and contrary to what we have always supposed, the average Englishman has a vivid imagination for noises and disturbances that the less acute ears of Western nations would fail to notice. The dynamos by Latimer Clark, Muirhead & Company are of the Siemens type and, what cannot be said of all English machines, run cool. The electrical regulation is done by a potential galvanometer connected to pilot wires laid in the trenches with the feeder wires, and connected to them at the points of distribution. This potential governor makes contacts which set in motion in one direction or the other a little motor which throws in or out resistances in the circuit. The fuses are of lead wires, the ends of which are joined to solid lead strips. The instruments of the Cardew, Ayrton, and Perry types are complete and conveniently arranged.

Ascending from this basement by a winding iron staircase, a floor is reached, designed for accumulators. The next floor is filled with carriages, and the upper one with offices. The final capacity of this station has been carefully considered in its design, and is 13,200 horse-power or 2000 light dynamos, and by the aid of accumulators 50,000 lights can be supplied. All foundations and steam and exhaust pipes have been laid for the full capacity. The mains and feeders are bundles of bare copper strips in 150 feet lengths stretched tight with tackle and soldered, and supported at the ends of each section of conduit. This is of U shape, the sections being joined by iron saddles, caulked with lead. The cover fits into grooves, and is made water tight with hemp and red lead. At each saddle a porcelain separator with three grooves contains and supports the conductors. As the sections are about 10 feet long, ebonite separators are also placed on top in each section. Attachments are made by drilling, tapping, and bolting the house mains to the street mains. At low points the conduits and junction boxes are drained. The coal used in this station costs delivered 24 shillings, or $6.00, per ton. The best Welsh navigation or smokeless coal must be used in London, and this, with the coal dues and expenses for teaming, makes the fuel bill more of an item in the expense account than would be the case with us if more economical engines were used. A second station is proposed in the northern portion of the district near Oxford Street.

The Kensington & Knightsbridge Company have at Kensington High bridge a station now in its fourth year, engineered and designed by Mr. Crompton. 7000 lamps were connected in July, and at the time of my visit, 6 P. M., with three hours more of daylight, the output of 50 amperes indicated that 100 lamps were in use. Three 90 horse-power Willans engines and three 550 ampere Crompton dynamos, and 2 sets of the Howell accumulators of 60 cells each formed the working plant. In July the starting hour is 7 P. M., and the machinery is stopped at 1 A. M., or when the cells become fully charged. During the remainder of the 24 hours the batteries supply current. These have an output of 100 per set. The batteries simplify regulation. The plant was being more than doubled in size, and Babcock and Wilcox boilers of 250 horse-power were being added. Other generating and storage battery stations are in process of erection or contemplated to supply this district. The cost of producing 1000

watts in Dec., 1888, was 2 cents, including all operating expenses and repairs, 5000 lamps connected and 67,500 units contracted at 16 cents per unit. The unit adopted by the Board of Trade and by one large parent company in this country is 1000 watts — 1 ampere at 1000 volts or any product of amperes and volts that will = 1000, and is nearly = 20 16 candle-power lamp hours or 100 cubic feet of gas. A dividend of 7 per cent was not distributed, but was devoted to extensions. The mains are laid in brick cemented culverts under the sidewalks. There is no depreciation to the insulating material which, as in the St. James Station, is that advocated by Captain Brophy, of Boston, *i. e.*, dry air. The bare copper leads are supported by glass insulators.

The Crompton system embodies groups of storage cells charged in series and placed at convenient points for distribution, 4 or 8 batteries in series, and 550 to 1100 volts in the charging main. The first of the type of cell employed, which is of the Plante style, were formed *in situ*, and having no capacity acted at first as regulators and slight storage. A battery costing $1000 three years ago is now valued at $800. Cells of newer types have a discharge of 1000 amperes and depreciate less than 5 per cent. The need for storage is caused by the large output for a short time, about 7.30 P. M., when the servants are preparing dinner and others for dinner in the chambers. Drawing rooms and dining rooms are then lighted. The shops do not close until 8 o'clock. A few motors are operated, and for these in London there is not a very good field. Elevators have not to any extent taken the place of the good old-fashioned stairway, safe without inspection, and besides it is difficult to compete with hydraulic power from water distributed at 700 pounds pressure per square inch. A 60-foot passenger elevator costs for water $36.00 per year by contract. The Kensington station has used the Aron meter exclusively.

"Dead as Chelsea" is not true of the part of London known by that name. Whatever may be said of the little city across the Charles and Mystic, Chelsea, Eng., is beyond all rivals the most enterprising electrically. On Manor Street is the plant of the Cadogan Electric Light Company. Storage batteries made by the E. P. S. Co. are placed in each house supplied, the voltage 30, 48, and 96 volts is given by different numbers of cells. With an output of 70 amperes, from 35 to 140 are supplied in each house, and Aron meters

measure the current consumed. It is intended to make use of the Edmunds' distributing system, wherein the batteries in consumers' houses are divided in groups and charged a portion at a time, the switching being effected by a small motor. The system is unique, and, under the supervision of the managing director, J. S. Sayer, may supplant earlier systems. The "Leeds" dynamos give 400 volts 70 amperes, have Gramme ring armatures and run at 800 revolutions, and are belted direct to Armington and Sims engines, 50 horse-power built, as well as the dynamos, by Greenwood and Batley.

Years ago in England all large powers were transmitted by gearing, and it was thought impossible to use belts. This prejudice had exercised great influence in the introduction of direct coupled engines, and has almost entirely prevented the use of leather belting. So, in this station the leather belts and American engines and boilers of the Babcock and Wilcox type reminded one of home. In this station boilers, engines, and dynamos are in one large room. Three sets of accumulators, A, B, and C, of nine cells each supply 66 amperes for exciting the field magnets of the dynamos, and are charged at the same time they energize the fields. The Worthington steam pumps, in fact, everything, is American except the dynamos and cables. The cables are composed of 19 strands of No. 14 wire, with double rubber insulation, and suspended from iron fixtures on housetops and a few poles. The length of the three circuits is 9 miles, 1000 yards being under ground in plain iron pipes. Engines are started at 6 A. M., and stopped at 9.30 P. M. One circuit is charged in the morning, second in the afternoon, third in the evening. Three thousand lights are connected, and an increase ordered. \$12.50 per year per light is charged in bar-rooms, \$6.25 for private homes, or by meter at 15 cents per unit. The iron stack, stayed and guyed as if to last for a century, must be taken down in two years, and a brick one built. Iron stacks or chimneys are not quite English. Coal used is the best Welsh smokeless, and costs 23 shillings per ton. The cells always contain two days' supply, but are charged to the gassing point daily. Sub-stations of batteries will be placed in stables behind the best houses, sufficient quarters costing \$75 per year. The overhead wiring is well done, the cables supported by leather from galvanized wires attached to glass insulators.

The Chelsea Electric Supply Company has adopted a system of

sub-storage stations, the inventor being Mr. King, of the E. P. S. Co. The main generating and storage station is at Draycott Place, Cadogan Terrace. The dynamos are built by the Anglo-American Brush Company. There is, as it were, a sub-station of accumulators in the same building. In the battery room there are 3 tiers of cells, in all 12 sets of 54 cells each. The cells are glass in wooden trays lined with sawdust. The boxes rest on glass insulators containing rosin oil. Each cell weighs 200 lbs., and is supported on wooden cross-pieces fixed to iron uprights. The regular discharge is about 60 amperes for 9 hours. Two sets run 3000 30-watt lamps of 13 candle-power. Traveling cranes assist in changing cells. The mains are laid under the sidewalks at the curb. Several sub-stations are undergoing construction, one was in operation at the time of my visit. It is situated in a stable at Clayton Mews. Eight sets of 53 cells each are attached to 2000 30-watt lamps, and furnish a constant and satisfactory supply of current Ventilation is effected by a fan driven by a 1-3 horse-power motor, but is seldom necessary. The feeders are at times automatically joined to C. E. M. F. cells of plain lead grids.

In such a station the batteries are divided into two parts. When the engines start, one set is supplying current for day consumption, the other is thrown into circuit and is charged, then switched onto the mains, and the second set is switched on the dynamo circuit and charged, and when this is completed it is put in multiple with the first set and begins to discharge. This is accomplished before the heavy lighting begins. The cells are cut out of the charging circuit automatically, when charged, by a master cell from which the gas evolved raises a gas-holder and makes contacts that allow current to move switches. The regulating devices are exceedingly ingenious, and though somewhat complicated work well. A great future is before this system if, as seems likely, it stands the test of actual work for a long time. The E. P. S. Co. guarantees the cells to have less than 12 per cent depreciation.

House lighting in England is considered of the first importance in central station work, and the "House to House" Electric Light Supply Company has done good work in several cities. Its station at Brompton is a model one. It is designed for 12 complete sets of plants of which 3 are now running. Babcock and Wilcox boilers are used, connected by copper tubes to the main steam pipe of welded

steel. Copper tube for the entire steam piping is common practice in England. The temporary partition of corrugated iron at the end will give room for nine more boilers in addition to the three now in use. The chimney is large enough for six. All exhaust piping laid under the floor is large enough for 12 boilers. The three engines are compound non-condensing of the Corliss type, and belted to the dynamos by seven separate ropes. They are steam jacketed, and with 140 pounds of steam develop 250 to 300 horse-power.

The Lowrie-Parker dynamos have revolving fields and stationary armature and make 350 revolutions, producing 60 amperes at 2000 volts. The exciters are driven from a small counter on the armature shaft. The details of this system are well worked out. The dynamos are often run in parallel, a feat not attempted elsewhere. To determine when two dynamos are in step a lamp is connected to two secondaries in series, the primaries being one in the circuit of each machine. When the phases of the two dynamos coincide the lamp burns brightly, and the switches are then thrown. The mains are under ground, of stranded wires insulated with india rubber.

All of the stations described thus far in London are removed from supplies of water for condensing purposes, and where coal of extra quality must be used to prevent smoke nuisance. To attain the high degree of economy in condensation, to avoid the expense of carting coal, etc., the London Electric Supply Company located a station at Deptford, five miles from the city, to which a current of 10,000 volt alternating will be carried in concentric cables running by the viaduct of the South Eastern Railroad and the Underground Railroad to substations at Charing Cross, etc., and there transformed to reduce the pressure from 10,000 to 2500 volts, which is distributed by underground mains in bitumen conduits to consumers, and again converted to currents of 100 or 50 volts. So gigantic an experiment as this was not entered upon by chance. A small station in the basement of Grosvenor gallery became a success a few years ago when Mr. Ferranti's system was adopted. Over 30,000 lights are run from this station. The mains are overhead on housetops. The E. M. F. employed is 2500 volts, so that the Deptford installation is not wholly experimental. The saving in the cost of coal is as 22 shillings to 8 shillings 9 pence, or as from $6 to $5.50 to $2.18. The engines now operating are upright marine compound condensing Corliss, working

at 160 to 200 pounds pressure. Condensation is not yet provided for. The Thames water or sewage is very dirty, and it is necessary to go out 200 feet from the dock at low tide to find water, at which a mud beach extends 75 feet from the wharf, — a mud beach so soft that vessels are not injured by resting on it.

The compound engines and exciters would for a small town be a large plant. But the large dynamos recently started are 30,000 light machines, and these are small compared with the monsters in process of construction. They will weigh 600 tons. The armature will be 42 feet diameter and the frame 45 feet. The speed will be 50 to 60 revolutions. These engines being two of 10,000 horse-power to each machine directly connected. The crank shaft alone will weigh 26 tons.

The boilers of Babcock & Wilcox type, by means of forced draft obtained from blowers driven by engines under boiler room, are capable of generating 800 horse-power each. The gases from the furnaces pass at will through economizers to a 130-foot stack. When finished in two stories there will be 48 boilers. Railways connect every part of the works and yard. The engine room has two large overhead cranes. There is a 50-ton crane at the end of the wharf, and a 3-ton crane is mounted on a platform car.

The quality of incandescent light in London is inferior. The light is not steady, never above candle-power, but of a dull red color, and is often referred to by envious gas engineers as 4-watt red-hot hairpins. The expert, the bane of all electric companies in the United States, has a cousin in the engineer. They are of the same class as the experts, only they know less. The height of their ambition is to become "attached" to the staff of some noted engineer, and superintend or direct practical work without ever learning it by hard work and experience. Engine drivers earn 30 shillings a week; they are little more than oilers; fitters keep machines in repair; steam engineers overlook all this work; the engineers of the staff oversee the steam engineers, and the engineers in chief receive the salary and get the honors. Manual labor is deemed menial, and young men of the middle class shun it.

At the close of the paper a large number of views of the London stations were projected on the screen.

MEETING 404.

The Engineering Building.

BY PROFS. F. W. CHANDLER, G. LANZA, G. F. SWAIN, AND MR. S. H. WOODBRIDGE.

The 404th and annual meeting of the SOCIETY OF ARTS was held in the Engineering Building of the Institute on Thursday, May 8th, at 8 P.M., President Walker in the chair.

After the reading of the records of the previous meeting the report of the Nominating Committee was presented, and officers were elected for the ensuing year.

The report of the Executive Committee was read and ordered placed upon the records. The President then announced the subject of the evening to be the New Engineering Building of the Institute, and introduced Prof. F. W. Chandler, who described the architectural features.

Prof. CHANDLER said: The Engineering Building of the Institute of Technology is built on Trinity Place, a short distance from the other buildings of the Institute. The structure measures 148 feet by 52 feet, and has six stories. Its height of 85 feet is the extreme limit allowed by the building laws when a wooden construction is used. Its position on the lot was very carefully considered in regard to future additions to the south on the property of the Institute; and, by mutual agreement with the abuttors, there will always be a clear area of 30 feet to the north.

The scheme of the building is what is known as modern mill construction. A row of cast iron columns, placed eight feet from center to center, runs lengthwise of the building, giving spans of twenty-four feet from column to wall. The strength of the brick wall is concentrated in buttresses opposite the columns, and thinner walls unite them, and because these thinner walls are not necessary for the stability of the building, the greater part of this space is occupied by windows, the heads of which extending between the beams, as there are no ceilings, to the underfloor gives that high light which is the most effective in lighting a large room. A pair of southern pine beams extends from each column to each side wall. These doubled beams

are in all cases bolted together with eight ¾-inch iron bolts to each pair, leaving a space of one inch between for ventilation, kept open by iron washers. The beams are framed to fit snugly around the columns, and the ends of the abutting timbers are fastened together by dogs of ⅞-inch iron, the ends of which are turned down and driven into holes in the beams. These timbers are also fastened at the under side by lag screws through the caps of the columns. The other ends rest on cast-iron plates one inch thick, and are carried into the wall eight inches, and one inch of air space is left about the ends for ventilation. To tie these beams to the walls a one-inch bolt is put through each pair of beams eight inches from the wall, and at the same time through the eye of another one-inch bolt which lies between the timbers, the nut end being on the outside of the building, and pressing against a cast-iron washer. Across these paired beams are carried plank under-floors of spruce, four inches thick in the basement and three inches thick elsewhere. These planks are laid with splines. The upper floors throughout are of maple and ⅞ inches thick. Between the lower and upper floors, in addition to the asbestos paper required by law, are three thicknesses of heavy deadening felt, and two of tarred paper.

The construction of the roof is like that of the floors.

It does not yet appear by whom the slow-burning construction, as applied to mills, has been evolved, or when was first made use of heavy timbers set wide apart carrying a solid floor. But for a long time after these floors were in use, even in Lowell, the roofs were bad either in form or structure until Mr. William B. Whiting, the Vice-President of the Boston Manufacturers Fire Insurance Co., suggested the adoption of what is called the deck roof, constructed like the floors, and the Engineering Building is a development of the Mutual Underwriters more than anyone else.

The structure throughout is of unusual strength, for the aim was to have a building which should be sufficiently free from vibration when the heavy machinery was running in the basement, to admit of experiments being made there, requiring delicate measurements, and because the four upper floors were to be chiefly used for draughting rooms. The iron columns decrease in size from the one in the basement measuring 11½ inches in diameter with a 1½-inch shell to the one in the sixth story, 6 inches in diameter with an inch shell. These

columns resting on each other have their ends carefully turned in a lathe to ensure perfectly accurate bearings,— the head of one column having a seat countersunk $\frac{1}{4}$ inch to receive the foot of the next column. In the mill proper these columns are of wood, but, on account of the great weight to be carried in this structure, much valuable space could be saved by using iron.

The beams of the basement floor measure each 11 inches by 18, those of the first floor 10 inches by 18, those of the second 7 inches by 16, and those above 6 inches by 16, and those of the roof 6 inches by 14.

There are no boilers in this building, the steam for heating and for power is brought from the boilers in the basement of the Rogers Building, about a thousand feet away, through a six-inch pipe buried under ground. The pipe is first wrapped in asbestos, and for further insulation it is inserted in a wooden log.

The heating system is partly direct and partly indirect, and with the indirect part ventilation is obtained by means of a Sturtevant blower. Nearly all the radiators have automatic valves, the temperature of the room regulating the steam supply to the radiator.

In connection with the heating should be mentioned that the window sashes of the north, east, and west sides of the building, and also a large skylight on the roof measuring 80 by 16 feet, lighting the upper draughting room, are double glazed, making a great saving in the expenditure of heat.

The exterior design is very simple, all effect being obtained by the principle of construction. The solid basement from which rises the long buttresses or pilasters, connected at the top by semi-circular arches, and the upper story with its thinner wall forming an attic, describes the design. And it is effective enough; it tells its story truly. The material is rough brick with a small amount of long meadow stone trimmings.

A heavy block granite foundation rests on 725 piles, averaging 40 feet long. All the heavy machinery in the basement have their piled foundations distinct from that of the building.

There can hardly be a more fire-proof structure. First, its isolation; then there is not a concealed space anywhere, no furrings on the walls,— the brick is the only finish, no ceilings, with its dangerous air space the depth of the floor joists,— the staircase is built open in

the same way,— the ventilation and heating ducts running from the basement out through the roof are of iron. Water is on every floor, and the standpipe is carried to the roof. An iron staircase, built in a brick tower, runs to the roof to serve as fire escape.

The building is occupied by the Mechanical Engineering and Civil Engineering Departments. The two lower stories are the laboratories of the Mechanical Engineering Department, and this department also has the two middle floors, which are devoted to drafting and recitation rooms. The two upper stories contain similar rooms for the Civil Engineering Department, and the library common to both departments.

THE LABORATORIES.

Prof. Lanza was next introduced to describe the laboratories.

Prof. LANZA said: These laboratories are now called the Engineering Laboratories, and the building is called the Engineering Building, because it is especially devoted to the engineering work of the school, both the general and the special. Thus, in its recitation rooms are taught the classes in mechanism, in thermo-dynamics and steam engineering, in hydraulics, and in strength of materials, all of which may be called general engineering studies, as all these subjects are taught, to a greater or less extent, to the students of civil, of mechanical, of mining, of chemical, and of electrical engineering. Besides this, all the drawing-room work of the students of these courses is done in this building, and all the purely professional work of the civil and mechanical engineering courses is carried on here; this including practically all the *engineering* work proper of the above stated courses. Hence it follows that it is the building where the purely engineering work is done for all departments of the school.

The Laboratories are really an aggregation of the following: —

1. A laboratory devoted to experimental work upon the strength and other resisting properties of materials used in construction.

2. A laboratory of steam engineering.

3. An hydraulic laboratory.

4. A laboratory where other engineering experiments are made, but which is not yet sufficiently differentiated to be divided into its component parts.

The objects to be accomplished by these laboratories are the following: —

First. To give the students practice in such experimental work as any engineer is constantly liable to be called upon to perform in the practice of his profession,— as boiler tests, engine tests, power determinations, etc.

Second. To give the students some experience in carrying on original investigations in engineering subjects with such care and accuracy as to render the results of real value to the engineering community.

Third. By publishing from time to time the results of such investigations, to add gradually to the common stock of knowledge.

The two lower floors of the building are entirely devoted to the Engineering Laboratories, thus increasing their capacity from about 5,550 square feet, as in the Rogers Building, to about 13,900 square feet. Cuts of these laboratories are shown here, and the following statement of the apparatus they contain is copied from the twenty-fifth Catalogue of the Institute: —

"The laboratory for testing the strength of materials is furnished with the following apparatus. An Olsen testing machine of 50,000 pounds' capacity, for determining tensile strength, elasticity, and compressive strength. A testing machine of the same capacity for determining the transverse strength and stiffness of beams up to 25 feet in length, and the framing-joints used in practice. Machinery for the measurement of the strength, twist, and deflection of shafting while running and under the conditions of practice. Machines for time tests of the transverse strength and deflection of full-sized beams; for testing the tensile strength of mortars and cements, and of ropes; for testing the effect of repeated stresses upon the elasticity and strength of iron and steel; for determining the strength and elasticity of wire; for determining the deflection of parallel rods when running under different conditions. Also, accessory apparatus for measuring stretch, deflection, and twist.

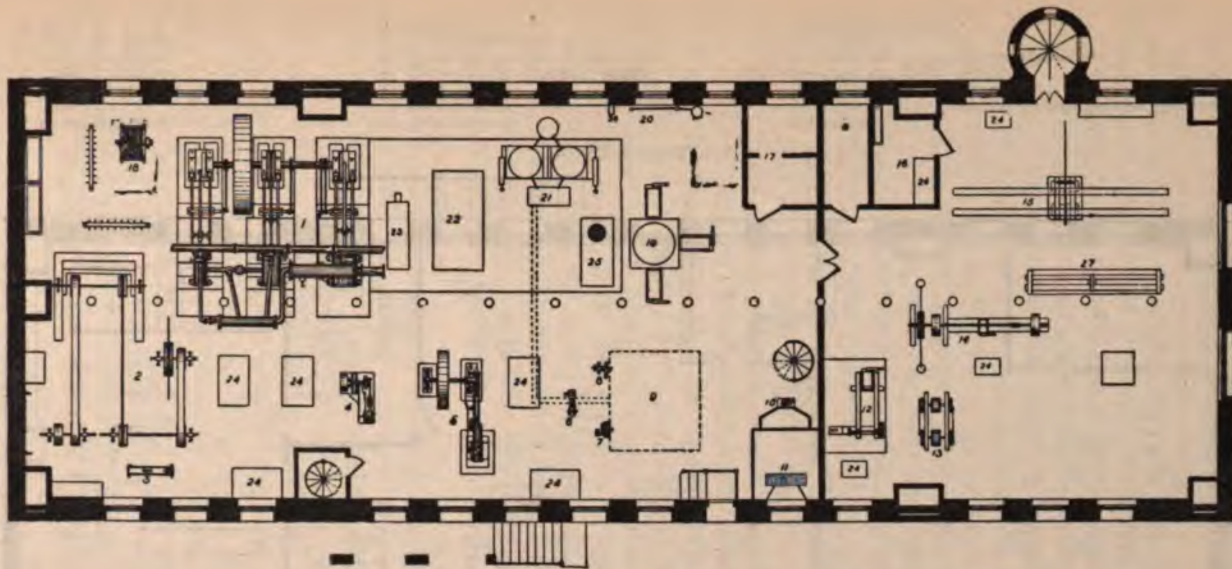
"The steam laboratory contains,— a triple expansion engine, with cylinders of 9 inches, 16 inches, and 24 inches diameter respectively, and 30 inches stroke, arranged in such a way as to be run single, compound, or triple, as desired for the purposes of experiment. This engine is of the Corliss type, and was built by E. P. Allis & Co. It will have a capacity of about 150 horse-power when running triple, with an initial pressure of 150 pounds in the high-pressure cylinder. It is connected with a surface condenser and all the other apparatus necessary to adapt it to the purposes of accurate experiment.

"This laboratory also contains a 16 horse-power Harris-Corliss engine, and an 8 horse-power engine, used for giving instruction in valve-setting, etc. It is also equipped with several surface condensers, steam pumps, calorimeters, mercurial pressure and vacuum columns; apparatus for determining the quantity of steam issuing from a given orifice or through a short tube under a given difference of pressure; apparatus for testing injectors; and with indicators, planimeters, gauges, thermometers, anemometers, and other accessory apparatus.

"The engineering laboratories are also provided with a number of friction brakes; with machinery for determining the tension required in a belt or rope to enable it to carry a given power at a given speed, with no more than a given amount of slip; with three transmission dynamometers; with a complete set of Westinghouse air-brake apparatus, including the parts belonging on the car and on the locomotive; with cotton machinery as follows, namely, two cards, a drawing frame, a speeder, a fly frame, a ring frame, and a mule, as well as accessory apparatus. There are also available for the purposes of experiment, in connection with the work of these laboratoties, two horizontal tubular boilers, one large Babcock and Wilcox boiler, and a Porter-Allen engine of about 80 horse-power, all situated in the Rogers Building; also another boiler, a 40 horse-power Brown engine, a number of looms, and other apparatus in the workshops on Garrison Street."

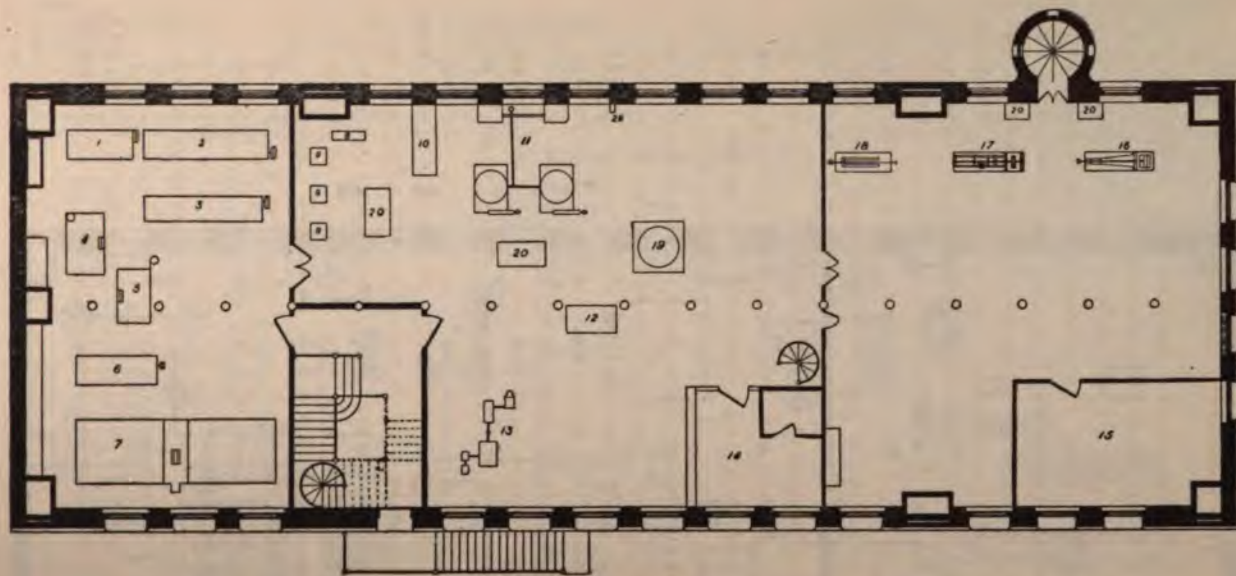
The most important addition to the equipment of these laboratories is that of the triple-expansion engine, inasmuch as it is the first triple-expansion engine of a practical size that has ever been arranged for making experiments; and by its means the laboratories are placed in a position which will enable them to do work for the triple engine of a character similar to that done for the compound engine by the United States Naval Engineers in 1874, and also to make such researches with a triple or a compound engine as were made upon single engines by Hirn, Hallauer, and others.

The laboratory with its present equipment furnishes the means, — 1st, of accommodating the number of students that now need this instruction, with an opportunity for some growth; 2nd, of giving good laboratory instruction to the students; 3rd, of carrying on investigations of importance in the engineering line. All this can be done, inasmuch as the building is adapted to the purposes of an engineering laboratory,— a fact which was never true of the Rogers Building.



BASEMENT, 150 × 50 FEET.

1. Triple Expansion Engine, 150 H. P.
2. Rope and Belt Transmission Testing Machine.
3. Engine Lathe.
4. Kendall Engine, 8 H. P.
5. Harris-Corliss Engine, 16 H. P.
6. Steam Pump.
7. Rotary Pump.
8. Centrifugal Pump.
9. Tank.
10. Fan Engine.
11. Steam Pipes for Heating Air.
12. Rope-Testing Machine.
13. Parallel-Rod Machine.
14. Shaft-Testing Machine.
15. Fifty Thousand Pounds Beam-Testing Machine.
16. Cement Room.
18. Dynamo, 500 Lights.
19. Wrought-Iron Tank for Hydraulic Experiments (5 feet diameter, 27 feet high).
20. Hydraulic Stand-Pipe (10 in. diam., 85 feet high).
21, 22. Cisterns.
23. Condenser.
24. Tables.
25. Turbine-Wheel and Tank.
26. Mercury Column.
27. Apparatus for Time Test of Wooden Beams.



FIRST FLOOR.

1. Drawing-Frame.
2. Speeder.
3. Fly-Frame.
4. Carding Engine.
5. Carding Engine.
6. Spinning Frame.
7. Mule.
8. Calorimeters.
9. Calorimeters.
10. Calorimeters.
11. Injector and Weighing Tanks.
12. Tank for Turbine-Wheel.
13. Westinghouse Air Brake.
14. Office.
15. Office.
16. Olsen's Fifty-Thousand Pounds Tension Machine.
17. Repeated-Bending Machine.
18. Cement-Testing Machine.
19. Tank for Hydraulic Experiments.
20. Tables.
26. Mercury Column.

THE HYDRAULIC LABORATORY.

At the close of Prof. Lanza's remarks, Prof. G. F. Swain was introduced, who described the Hydraulic Laboratory.

Prof. SWAIN said: The erection of the new engineering building of the Institute of Technology, to be occupied by the departments of Civil and Mechanical Engineering, offered an opportunity for a considerable extension in the Engineering Laboratories, and an attempt has been made to improve this opportunity by laying the foundation for a laboratory for hydraulic experiments, which should be so arranged as to permit of the carrying out of any experiments in hydraulics which it is practicable to perform within walls. Hydraulic experiments on a large scale must necessarily be performed out of doors, since the measurement of large quantities of water requires apparatus and appliances which cannot be accommodated within walls. Thus, the weir experiments of Mr. Francis, at Lowell, were made by taking the water from one of the canals, and using a lock as a measuring basin; those of Messrs. Fteley and Stearns, at South Framingham, were made by using a portion of the Sudbury River Aqueduct as a measuring basin; the orifice experiments of General Ellis, at Holyoke, were made in connection with the fall between two levels of the canal at that place; and the recent elaborate and careful experiments by Mr. Freeman on the flow of water through fire hose, the discharge of nozzles, and the height of jets, were made at Lawrence, where the hydrant system of one of the mills, as well as the city water supply, could be made use of.

But while experiments such as these are clearly excluded from among those which can be made in connection with a hydraulic laboratory in an institution of learning, there remain a large number which can properly be conducted within doors with the aid of suitable apparatus, and which, though they may be on a small scale as regards the quantities of water employed, nevertheless offer a large field for scientific investigation. The new laboratory of the Institute, as already stated, has been planned with a view to affording opportunity, as the work is extended, for carrying on any experiments which are thus practicable; that is to say, in the following directions: —

1. Experiments on the flow through orifices of small size, both free and submerged, and either sharp-edged, rounded, or fitted with

inside or outside mouth-pieces of various kinds, and under heads ranging as high as above seventy feet.

2. Experiments on the flow of water over weirs of small size, either free or submerged.

3. Experiments on the loss of head in small pipes of various kinds.

4. Experiments on the loss of head due to bends, curves, valves, diaphragms, or other obstructions causing sudden changes of velocity.

5. Experiments on the distribution of velocity in different parts of a liquid cross-section, either of a jet from an orifice, of a sheet discharged over a weir, or of a liquid flowing in a pipe.

6. Experiments on different water meters, including Mr. Herschel's Venturi meter, as well as the ordinary forms in the market.

7. The testing of small turbines and of various other small motors.

8. Experiments on the pressure of jets against plane or curved surfaces, and on the resistance of standing water to the motion of surfaces of different shapes through it.

9. Experiments on the siphonage of traps, and on other matters connected with plumbing arrangements of houses.

The development of a laboratory which shall admit of experiments in all these lines must necessarily be slow and expensive, and the laboratory in the Institute, being only a few months old, is not yet fully equipped to carry on any of these experiments excepting those on the flow of water through orifices. It is believed, however, that the foundation has been laid for the rapid development of research in the remaining directions which have been enumerated, and the object of the present paper is briefly to describe and illustrate the apparatus thus far provided or proposed.

In order to be able to work with large heads, and to be independent of the city water supply, as well as to provide for the varied experiments enumerated, it was first necessary to erect a tank and standpipe. The tank is shown in Figure 1. It is made of "Shell" steel $\frac{1}{4}$ inch in thickness, is 5 feet in diameter and about 28 feet high, resting on a concrete foundation and extending up through two floors. It consists of six courses of steel, with girth seams single riveted, and longitudinal seams double riveted, and with heads of $\frac{7}{16}$-inch steel dished, as shown in the figure. It is provided with orifices as follows: —

In the lowest course, a man-hole 24 inches by 12 inches at M; at P, a flanged nozzle with elbow for connecting to 10-inch standpipe, as shown in Figure 15.

In the second course, a 10-inch orifice at G, a second at F, a third at D, and a fourth at C. The orifice at F may be used, if desired, for connecting with a small turbine placed below the floor. That at G is for experiments on submerged orifices. Those at D and C are for experiments on free orifices, or for connecting lines of pipe with the tank. Enclosing the orifice at G, an angle-iron and two bent plates are attached to the side of the tank, as shown, to which a wooden tank extending horizontally and resting on the floor is to be attached. In this wooden tank will be placed a weir, and the water will flow through the submerged orifice at G, or through a submerged mouth-piece, either inside or outside, and either converging or diverging, and will then flow over the measuring weir. The orifice C is fitted for experiments on free orifices, as will subsequently be described. The orifice D is to be fitted with a piece to which pipes can be attached as desired, thus enabling the losses of head at diaphragms, valves, curves, etc., to be studied. On the same level with the orifices D and G connections are made for mercury gauges.

In the third course, a $1\frac{3}{4}$-inch orifice at G'' and another at C'', nearly above the large orifices G and C. These small orifices are for the shafts of the hand-wheels for raising the gates over the large orifices, as will presently be explained.

In the fifth course, orifices similar to those in the second course; and in the sixth course, orifices similar to those in the third course; thus rendering it possible to carry on experiments simultaneously upon two floors of the building. The top of the tank is provided with a flanged nozzle for connecting with the 10-inch standpipe, as shown in Figure 15.

The size of the tank is such that, with the orifices which it will be practicable to use, the velocity in the tank will be so small that it may be neglected, and the disturbance due to the inflowing water from the standpipe will also be small. Nevertheless, two gratings have been arranged, one at the top and one at the bottom. These gratings consist of plates of $\frac{1}{8}$-inch iron perforated by $\frac{1}{2}$-inch holes about an inch apart. They are made in three pieces, and rest upon angle-iron brackets riveted to the inside of the tank. The tank itself rests upon cast-iron supports, as shown in Figure 1.

The general arrangement of the tank and standpipes is shown in Figures 15 to 18. Figure 15 shows the plan of the sub-basement, with the location of the tank, the rotary pump, and the steam pump. The tank *a* is connected, as shown, by the top connection *e* and the lower connection *f* to the 10-inch wrought-iron standpipe *b*, which, as shown in Figure 17, extends to the top of the building, and is closed at the top. The connection *f* is tapped by the small pipe *g*, by means of which the water may be drawn out of the system into the cistern *h*. The pumps take water from this cistern *h* and deliver it into pipe *k*, which, as shown in Figure 17, is arranged to carry it directly to the standpipe through the valve *s*, or to the 3-inch pipe *c* through the valve *t*. For use in the hydraulic experiments, the valve *s* is closed and the valve *t* opened, the water being thus delivered into the 3-inch pipe *c c*. From this pipe the flow into the 10-inch pipe is regulated by the valves *n*, which enable the head in the 10-inch pipe to be maintained at an almost perfectly constant level. Any excess of water overflows through the pipes *m* into the discharge pipe *d*. The pipe *c* therefore serves as a regulator of the head, and it has been found to fulfil its purpose admirably. Attached to the standpipe *b*, and running from floor to ceiling, in each story, is a glass gauge placed in front of a graduated scale reading to hundredths of a foot. These gauges are enclosed in wooden boxes, which may be opened on the front and on one side, and which are placed so as to receive light directly from adjacent windows. The water is taken by the pumps from the cistern *h*, passes through pipes *k* and *c* and through the valves *n* into the standpipe *b*, thence through the connection *e* or *f*, or both, into the tank, from which it is discharged through orifices, or in any other way desired, and the discharge measured. Measurements are made by weighing the quantity of water discharged in a given time, the water being returned to the cistern *h*, and thus used over and over again.

The same apparatus, by suitable arrangement of the valves, will be employed in making tests of the pumps.

The city water pipe is connected with the standpipe system at *x*.

The soil pipe *dd* is arranged with single and double Y's in a way which will allow the carrying out of all kinds of experiments on the siphonage of traps, as mentioned under head 9 on page 138. This pipe is arranged with an ordinary trap at the foot, as shown in Figure 16, and it discharges into the cistern *h*, as shown in Figure 15.

The details of the arrangement for measurements with simple free orifices are shown in Figures 2 to 14. In experiments of this description it is of course essential that the orifice shall be placed in a plane surface. It was therefore necessary to arrange the apparatus so that the curvature of the tank itself should not affect the flow. For this purpose a composition casting *a* (Figs. 2 and 3) is drawn up to the tank by eight $\frac{5}{8}$-inch bolts, as shown in Figure 3, which are screwed into the hub of the casting. The greater part of the casting is only $\frac{1}{4}$ inch in thickness, with eight strengthening ribs, as shown in Figure 2. In this casting is placed a piece, *c*, which is held in position by a ring-nut, *dd*, which can be screwed or unscrewed by a spanner. When it is desired to use large or long orifices the piece *c* will contain the orifice, and by having various pieces *c*, with orifices of different shapes and sizes, numerous experiments may be carried out. The composition casting *a* is thickened on one side to $\frac{3}{8}$ inch, as shown in Figures 2 and 3, to allow of the insertion of a sliding piece by means of which the horizontal dimension of a rectangular orifice may be varied, keeping the vertical dimension constant. When small orifices are to be used, it is not desirable to have them cut in as large a piece as the piece *c*. This piece *c*, therefore, as shown in Figure 3, is arranged to take a second piece, *o*, held in place by a second ring-nut, *d'*. Small orifices are made in pieces like the one *o*, as shown in Figure 3, and are of different sizes and shapes.

It is desirable that one orifice may be removed and another substituted in its place without completely emptying the tank. For this purpose a gate is designed to slide on the back of the casting *a*, so that, when it is desired to remove one orifice, the gate may be lowered and the water thus shut off, and a new orifice substituted in place of the old one. The gate may then be raised and the experiments continued. This gate and the fittings connected with it are shown in Figures 4 to 14. Figure 4 shows a view of the gate from the inside, Figures 5 and 6 horizontal cross-sections, and Figure 7 a vertical cross section. The gate is of cast iron, ribbed as shown, and is arranged to slide in guides bolted at the bottom to the casting *a*, and at the top to the tank. These guides are shown in Figures 8 to 11. In order that the gate may be raised without having to overcome the friction due to the pressure of the water over the entire surface of the gate, the rod *r*, by which the gate is raised, is attached to an

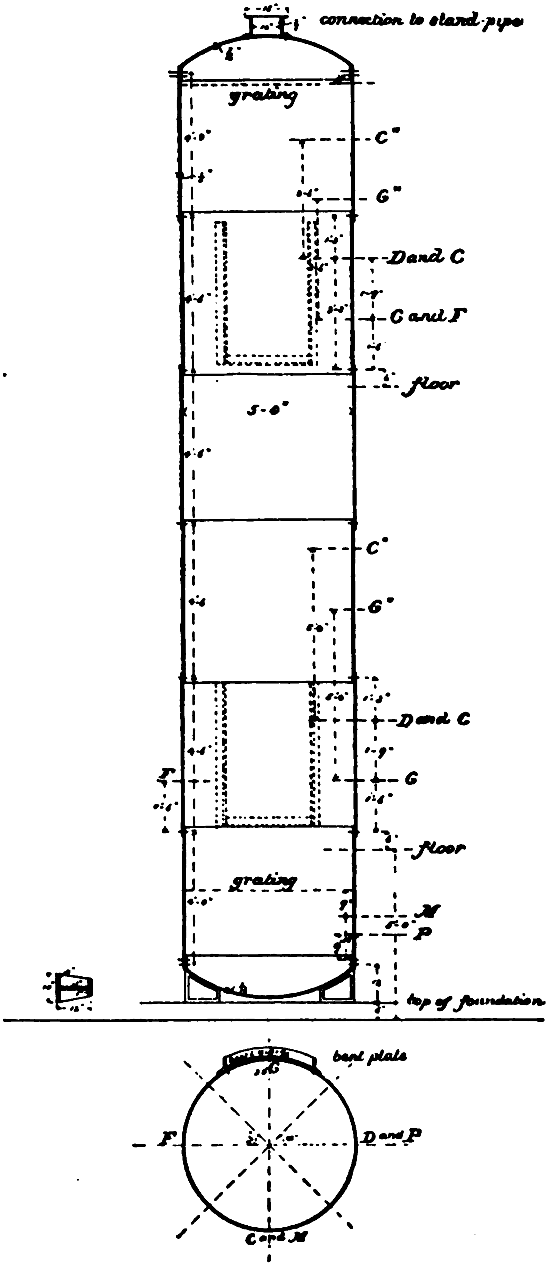
angle-iron, L (Figs. 4 and 7). When the gate is to be raised from the position shown in Figure 7, the angle-iron L is first raised until it strikes against the rib above it. This raising of L opens the orifice d, thus allowing water to pass through the gate, and equalizing the pressure on the two sides, except over the small ring forming the bearing surface, the friction due to the pressure on which is, therefore, the only friction to be overcome. The discharge orifice may be meanwhile closed by a plug from the outside, if necessary. When the gate is lowered, its own weight carries it down until it reaches the stop s. The rod is then forced down, closing the orifice d. Figures 12 to 14 show the hand-wheel, shaft, and stuffing box, by means of which the gate is raised, and require little explanation. The rod shown in Figure 7 is in its upper part a rack running in the space r (Fig. 12).

Only one further point calls for explanation regarding the arrangement of the gate and stuffing box, namely, the modifications necessary for the case of inside mouth-pieces. When such mouth-pieces are used, the gate as shown would of course be inapplicable, and a new seat must be provided for it, so that it will pass clear of the inside mouth-piece. It is intended to accomplish this by bolting on to the composition casting a (Fig. 2) a circular channel-shaped rib, and adding new guides for the gate, thus making its seat at any desired distance back of the inside face of the casting. At the same time, in Figure 12, the pinion will be removed from the position shown, and placed outside of the bearing, where the collar is shown in the figure, and the collar placed on the inside. A new guide for the rack will then be bolted on, as shown by the dotted lines.

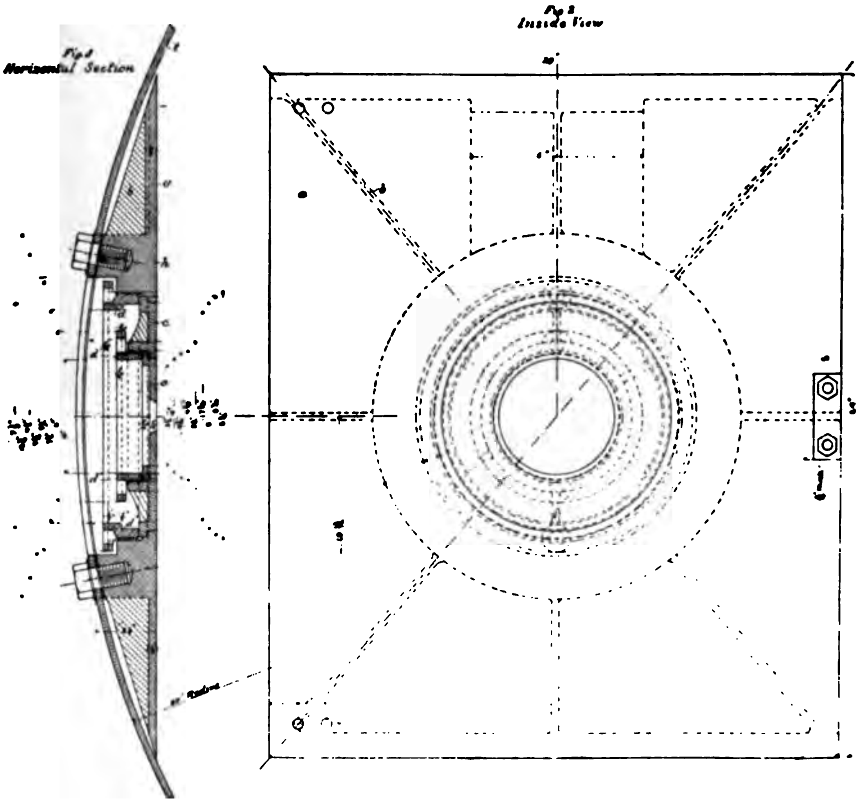
As the new engineering building has been occupied only since February, 1890, and the hydraulic apparatus is thus but a few months old, the only apparatus thus far in use is that for measuring the flow through simple, free orifices, and for making tests of pumps. It is hoped, however, that the remaining apparatus will be provided in the near future. The tank and the standpipe system already procured furnish the foundation, and upon them the other apparatus may readily be built up. Experiments upon meters and upon motors may also be carried out without difficulty; and, in fact, the possible lines of research are so varied that it is hoped that the establishment of this laboratory may lead to many useful results, and that it may contribute in some measure to the advancement of hydraulic science.

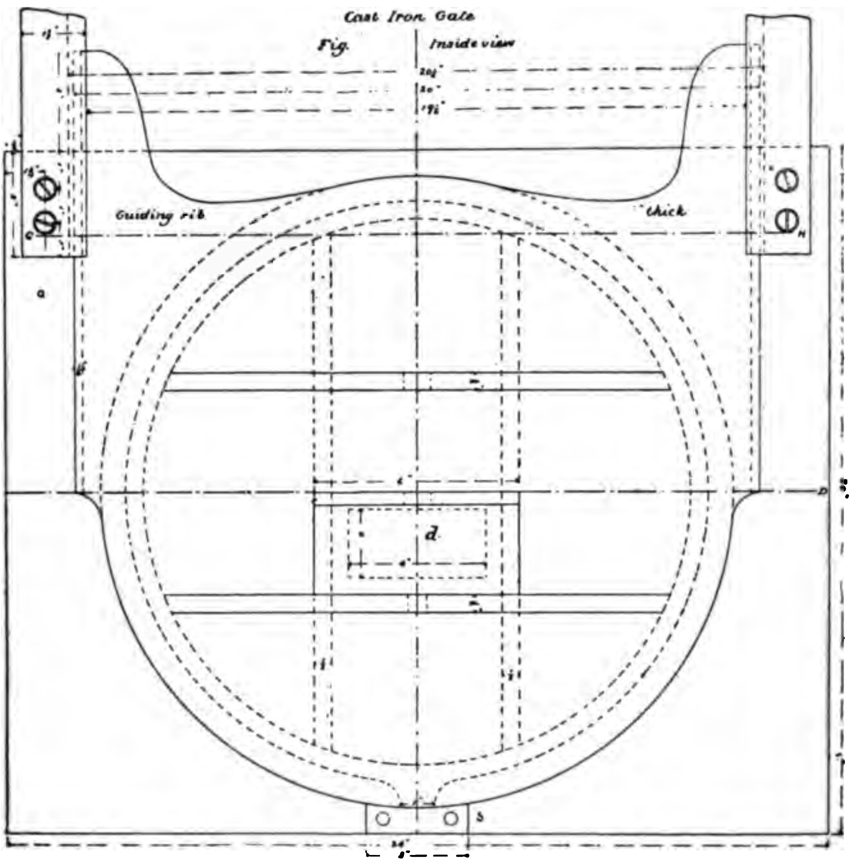
Steel Tank

Fig. 1.



Details of Horn Casting





Section on CD

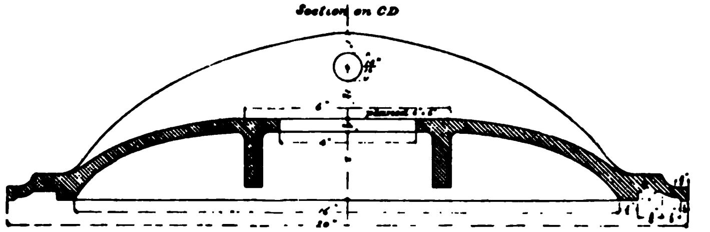


Fig. 5

Section on GH.

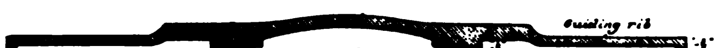
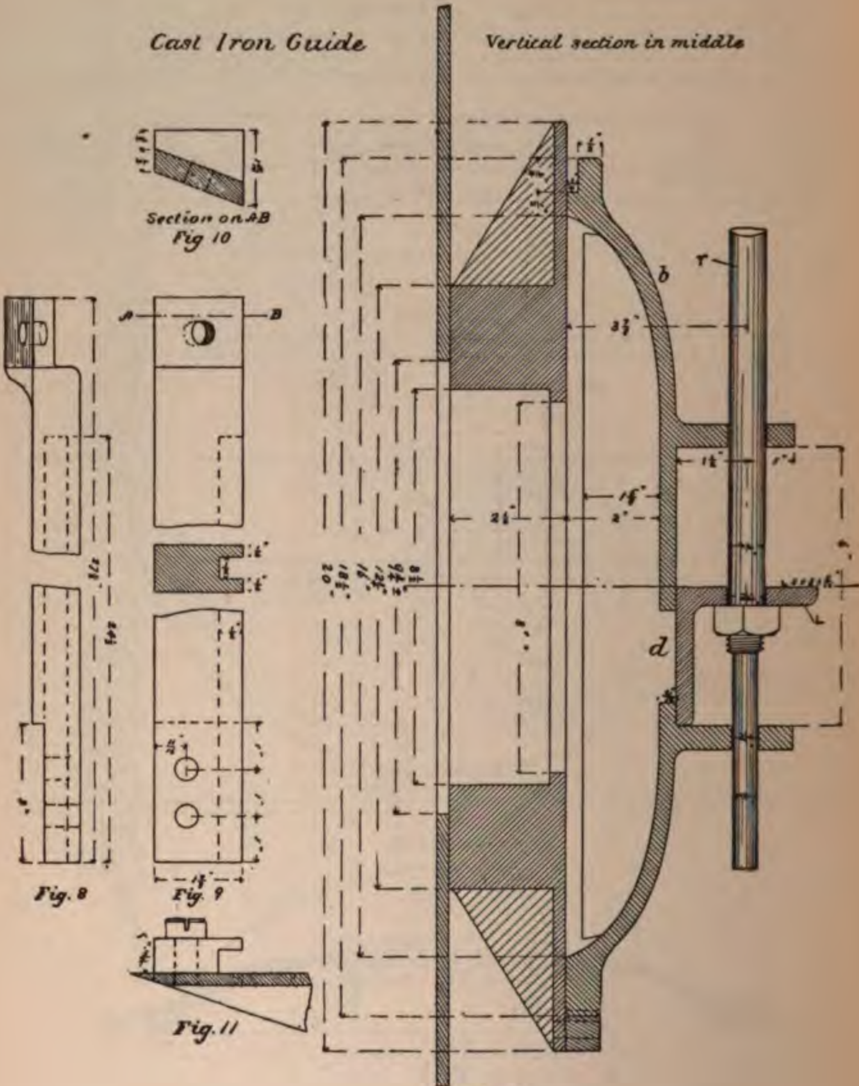


Fig. 6

Cast Iron Guide

Vertical section in middle



Section on AB

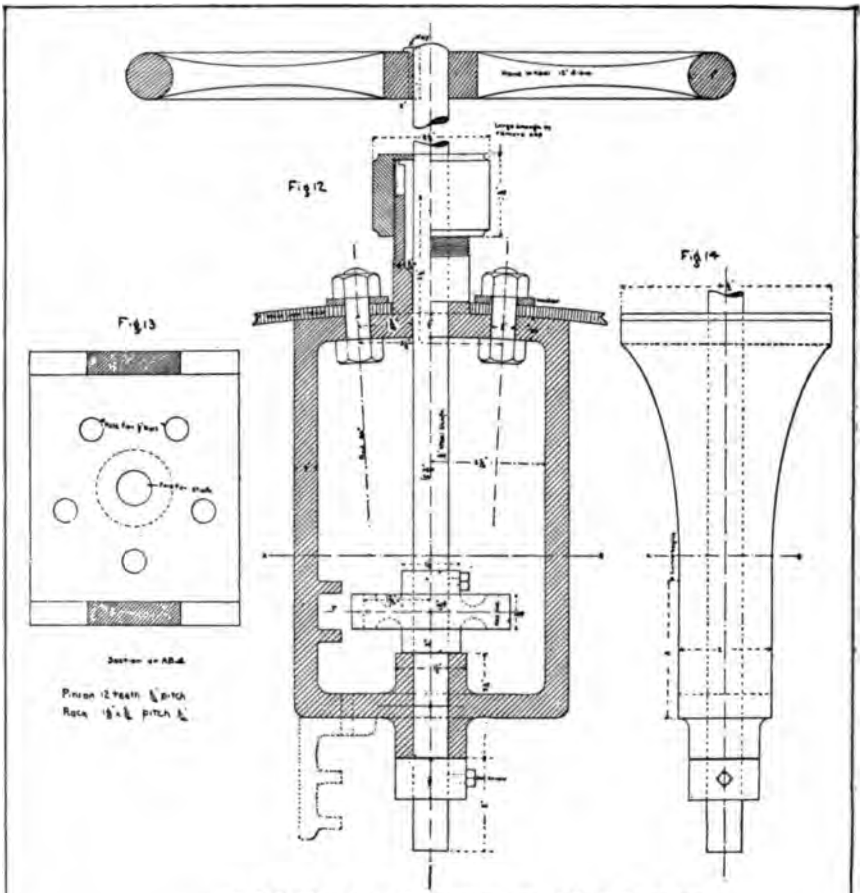
Fig 10

Fig. 8

Fig. 9

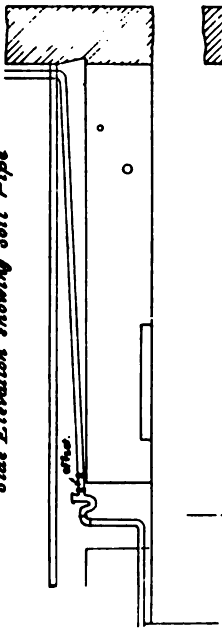
Fig. 11

Fig. 7



Shaft, Stuffing-box, etc., for raising gate — M.I.T. H^d Testing Tank

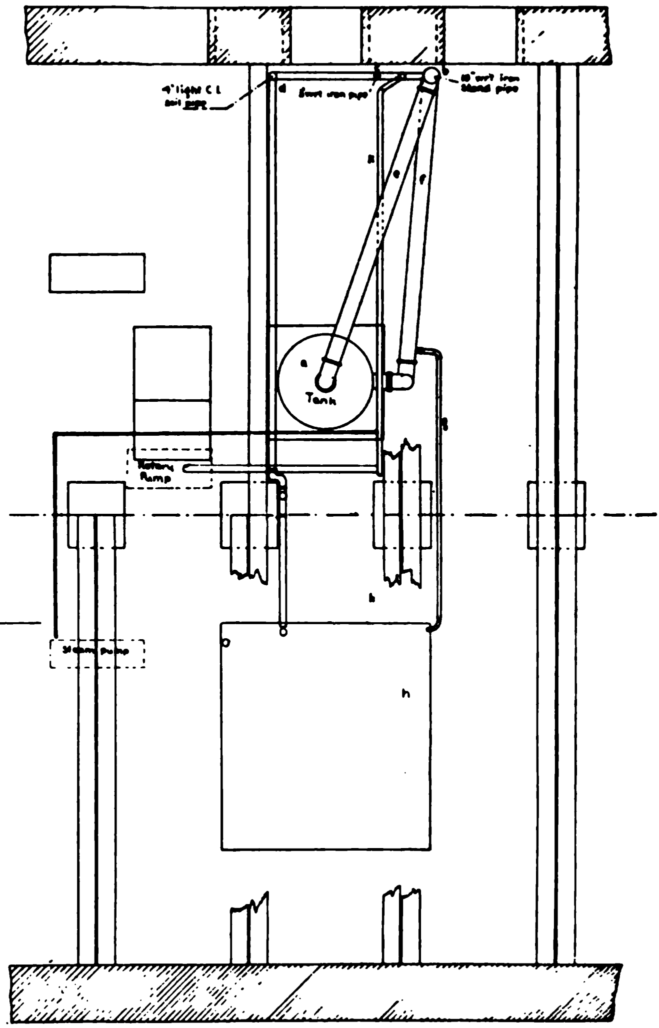
Fig 16



Side Elevation showing Soil Pipe

Fig 15

Plan of Sub-basement



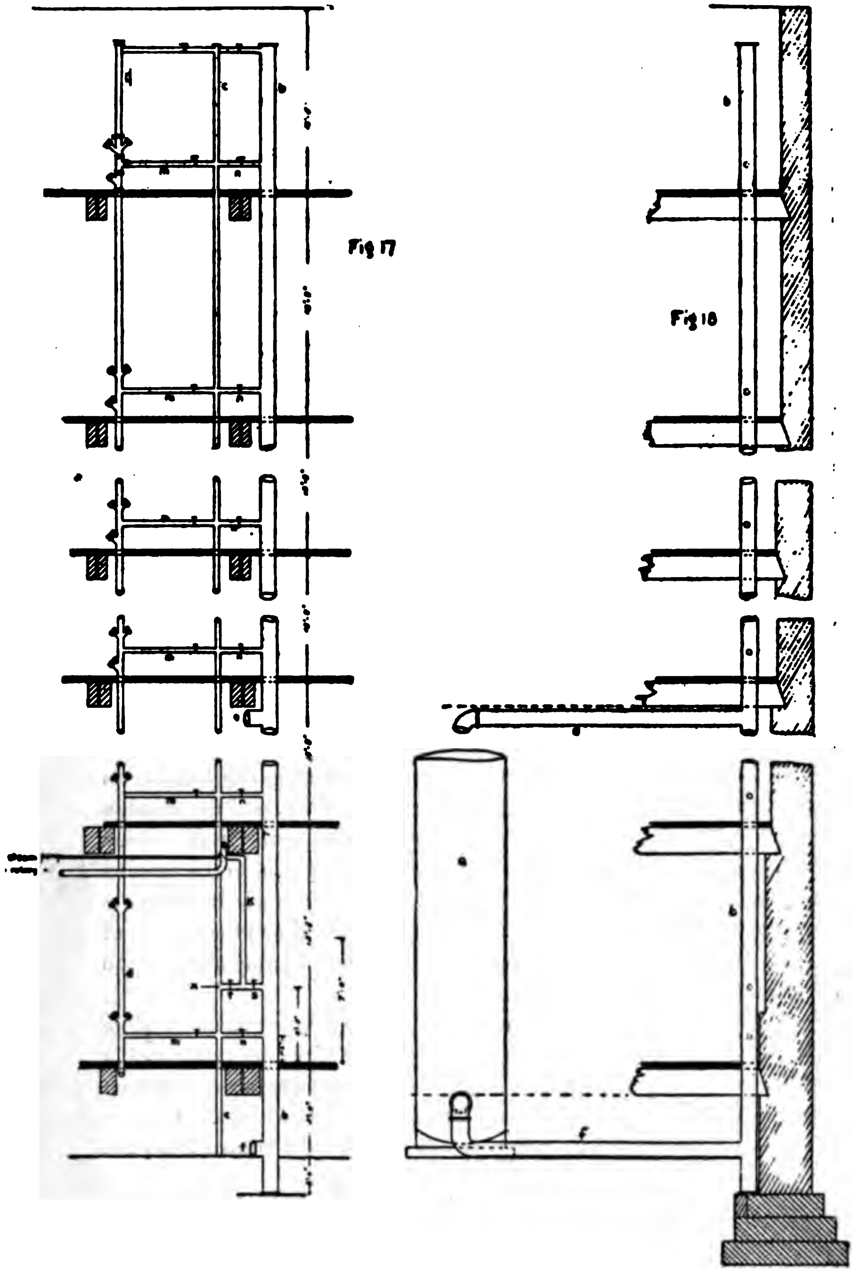


Fig 17
Fig 18

HEATING, HEAT REGULATING, AND VENTILATING.

At the close of Prof. Swain's paper, Mr. S. H. Woodbridge was introduced, who described the System of Heating, Heat Regulating, and Ventilating.

Mr. WOODBRIDGE said: This building is without interior walls other than light partitions, and all available external wall space is demanded for piers and windows. Locations were allowed for eight vertical flues (F) Fig. 1, varying from 9 to 12 sq. ft. in cross-section, for the supply and discharge ventilation of the thirty and more rooms. The rooms were arranged by their intended users with only partial reference to the fixed location of flues, and connecting air ducts were disapproved as unsightly. The great value of the basement floor space imposed a limit of 10′ x 12′ on the area to be surrendered to ventilating purposes. The use of the concrete floor of the sub-basement for apparatus, above and about which the basement floor is removed, precluded the use of this space as a distributing air chamber, and compelled the building of a continuous duct about the perimeter of the sub-basement, with one cross duct beneath the fan and into which it discharges at A–A, Fig. 1. The main duct, except where engine beds encroach upon it, is 15 sq. ft. in cross-section. The cross duct has nearly twice that area. The control of the air quantities to be moved in one direction or another within these ducts is effected by movable deflectors, one under the fan, and one at each end of the cross duct, Fig. 1.

The perimeter ducts have for three of their sides the foundation wall of the building, the sub-basement concrete floor, and the wooden floor of the basement. The fourth side is of galvanized iron, secured by nailing to wooden strips set in the concrete and nailed to the wooden floor and beams. A free use of elastic cement was made in all joints between metal and wood, and of paint in all locked or other joints of the sheet metal, and provision made for a possible settling away of the concrete from the wooden floor.

To clear the laboratory ceiling and the floor space of all possible obstructions and the unsightly appearance of piping, the steam mains and branches, traps, etc., are placed within the air conduits. All such steam pipes are carefully pitched and drained and covered. In spite of the latter precaution the temperature of the air in transit from the fan to the most remote flues is raised some 12°.

The eight vertical ducts are of necessity made to serve the dual purpose of supply and discharge. To adapt them to such purpose, a diaphragm is fixed in such way as to provide two channels having areas proportioned to the quantities of fresh and spent air to be moved through them to and from the successive stories, Fig 3. These diaphragms are made of sheet iron, which is secured by methods effectually preventing the leakage of air from the plenum into the exhaust conduits. Wherever practicable, the diaphragm is so placed as to remove the supply conduit from the outer walls, and to bring the discharge conduit against them.

Because of the small space occupied by the entire system, velocities of the air moved must be high. To secure to each register of the lower stories its proportion of air, and to prevent its going by such register under the momentum of its movement, deflectors are used, the area of each and the angle at which it is set controlling the air volume issuing from each register. Similar deflectors, set in a reverse position, are used for the outlets from the upper stories. To thoroughly break up and diffuse the swift flow of cool air in solid current from the register, diffusers, such as are shown in Fig. 1, are used with gratifying success.

The building accommodates some three hundred students, and the air supply is nearly 2,000,000 cu. ft. per hour, the fan running at 250 revolutions. The students are massed now here now there in class rooms, drawing rooms, and laboratories. Provision is made for a corresponding distribution or concentration of air supply, but the results without such alteration are so generally satisfactory that the valves are not used. Within the best filled rooms the largest proportions of carbonic acid thus far found are $\frac{7}{10000}$ to $\frac{7.5}{10000}$, and the uniformity of the proportions in all parts of the rooms has been found exceptional.

The warming is effected by three systems. Because of the large amount of steam work done in the basement, air must be supplied in large quantities, and at a temperature ranging from 45° to 55°, according to laboratory work and outside conditions of weather. The eight distributing flues cannot supply air to the several floors or rooms at different temperatures. They must supply it at the temperature required by that room above the basement most easily warmed to the point desired. Therefore, it becomes necessary to provide means for supplying air through one system of conduits to the basement at, say

50°, and to all rooms above the basement at 70°, and to further warm the air by direct means in such rooms as require supplementary heat.

The air is heated before it reaches the fan to 50°, a "Standard" metallic thermometer mounted in the fan case indicating the temperature, which is controlled by regulating the steam pressure in the coil. In moving under pressure through the sub-basement conduits the air leaks generously, as was anticipated, through innumerable small vents, the current being no where sensible, though the aggregate volume amounts to some 750,000 cu. ft. per hour. Reaching the base of the flues, the air passes through steam coils so made and placed that the flue area is not obstructed. The control of steam to these coils is by means of the Johnson electric regulating apparatus, the thermostat being hung on a crane before the supply register on the third floor. Whatever the temperature in the sub-basement conduits, the air supply to the rooms may be maintained at 70° or 72°, the range being confined within these limits by the automatic action of the regulator.

Within the rooms are placed wall steam pipes, the steam supply to which is regulated by the Johnson automatic apparatus, the thermostat being exposed within the rooms. For the quick warming of the building, the sub-basement conduit temperature may be run up to 100°, and the flue thermostat may be swung away from the register front. Air at such times may be rotated through the building instead of being taken from the outside.

The construction and arrangement of the auxiliary heater, Fig. 4, at the base of the flues is a matter of interest, because well suited to a successful working of the automatic method of steam supply. The steam enters at the top and through a valve so throttled that when the main conduit air is at its coldest the steam flow will be nearly continuous. The coil drains through a check valve. Without such an arrangement the temperature within the flue would fluctuate through a considerable range, for on the wide opening of the supply and return valves steam would enter freely at both ends and suddenly heat up the coil and the flue. It is desirable that the steam flow should be as nearly continuous as possible, and sufficient in quantity to warm the air passing through the coil. If the supply-valve is throttled, the drip-valve must be closed until the pressure within the coil is sufficient to force the accumulated water outward against the steam pressure. A

throttled drip-valve would allow steam to back into the coil and cause pounding. But the check-valve holds back the steam and allows the condensation to collect until its weight and the steam pressure combined force the valve open and the water out. The filling of the pipes with condensed water serves also the useful purpose of automatically regulating the length of their heated parts, and aids in maintaining the even temperature sought in the flues.

The heating is for the most part done by the exhaust steam of engines and pumps used in the building, and to avoid the possibility of returning oily water to the boiler the condensation is passed into the sewer. For the purpose of cooling this water; and of utilizing its heat, it is passed through 800 feet of continuous 1¼" pipe, made into a trombone coil 38 pipes high, 7' long, and 3 pipes deep, placed before the inlet window, Fig. 2. In mild weather the condensation is so small that it goes to the sewer cold. When the outside temperature is low that of the chilled water is higher, the rate of condensation slightly exceeding that of the chilling. The maximum rate of flow in severe weather is about 1 cu. ft. per minute.

The fan and combined heater, with directly attached engine, is of the Sturtevant pattern and make, with a large by-pass over the heater. The fan is 6' in diameter, and at 250 revolutions per minute supplies 33,000 cu. ft. of air. Outside the inlet window a roaring sound of rushing air may be heard, due to the high volocities inflicted on the air in transit through the coil and fan because of want of space to give it larger passage and lower velocity. Within this sound is not heard, partly on account of the noise of moving machinery.

The low pressure under which the heating system is worked and the irregular flow of condensed water, due in part to the intermittent supply of steam to the pipes, make the use of any ordinary steam trap impracticable. The method adopted for the relief of the New Building system having given entire satisfaction, it has been adopted in this system also. It consists of a syphon trap made of a 4" pipe 18' long driven vertically into the ground, bushed at the top and tapped at the side. Through the bushing runs a 2½" pipe to within 1' of the bottom of the large pipe. This pipe is bushed at the top, tapped at the side, and open at the bottom. The tap receives the water from the returns. The bushing receives a 1" pipe, which drains the supply main at a higher pressure than the return, and runs inside the 2½" to within 1'

of the bottom of the large pipe. Within the trap there may, therefore, be two pressures and two heights of water columns on the steam side, one vent discharging the water of both. The only resistance or friction is that due to the flow of water through the large pipes.

All steam for the building is brought from the Rogers building through an underground 6″ pipe, about 1000′ long. The water condensed in the heating apparatus is metered, and the record preserved for the purpose of record and investigation.

The cost of the complete instalment was nearly as follows: —

Fan, engine, main coil (1000 square feet), cooler, &c., ...	$1445
4580 sq. ft. of direct steam surface, flue coils, mains, fittings, and placing, ...	4490
Construction of ducts and sheet-iron work, ...	900
Johnson's electric service, ...	1355
Pump, Locke's regulators, sunken siphon-trap, covering mains, &c., ...	1775
Total, ...	$9,965

The direct heating surface is as great as though the heating of the building depended solely upon it, as insufficient boiler power threatened to make the use of the ventilating system impracticable in severe weather. Furthermore, if air is passed into the rooms at the temperature at which it is desired to keep such rooms, to maintain that temperature, the direct surface must be as large as would be required for heating by direct radiation.

The system is practically a dual one, the capacity of either part being enough for the heating of the building. The ventilating system includes the main heater, cooler, fan, engine, duct, supplementary heaters in flues, &c. Its cost may be put at $3500, and the balance may be charged to the heating plant. The total heating surface is about 1 sq. ft. to 110 cu. ft. of space.

Handicapped by the conditions imposed, the work is of interest not so much as an illustration of a perfect system as of what may be accomplished under difficulties.

The following table puts the arrangements for the ventilation of the New Building in contrast with those for the Engineering Building: —

	New Building.	Eng. Building.
Area of inlet windows, ...	106 sq. ft.	33 sq. ft.
Area through steam coil, ...	120 "	20 "
Area of fan mouth, ...	65 "	13.3 "
Area of fan discharge, ...	150 "	12.2 "
Area of floor occupied by fan room and heating chamber, ...	720 "	120 "
Area of main heating coil, ...	2200 "	1200 "
Area of flues for supply and discharge of air,	240 "	96 "
Number " " " " " " "	83 "	8 "
Air volume supplied, cu. ft. per hour, .	3,600,000*	1,950,000
Fan revolutions, ...	80 to 100	250

* In mild weather this is increased to 6,600,000,— fan revolution 100, and indicated horse-power expended 17. The fan is now run by an independent engine, and not as heretofore at a fixed speed.

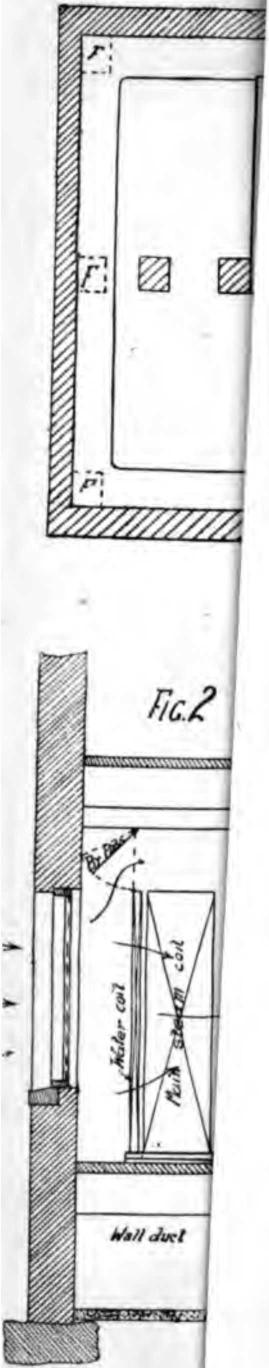


FIG. 2

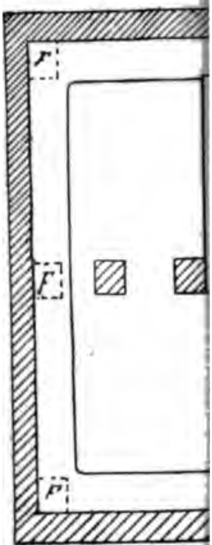


Fig. 2